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**OAK RIDGE
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The Loves Creek Anaerobic, Upflow (ANFLOW) Pilot Plant: Performance Summary

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T. L. Donaldson
R. K. Genung
A. L. Rivera
C. W. Hancher

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DEPARTMENT OF ENERGY

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Chemical Technology Division

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PERFORMANCE SUMMARY

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Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
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ABSTRACT

The performance of an anaerobic, upflow (ANFLOW) fixed-film bioreactor has been studied on a near-commercial scale with a $190\text{-m}^3/\text{d}$ facility in Knoxville, Tennessee from August 1981 to October 1983.

During treatment of low-strength municipal wastewater before primary sedimentation, the effluent met the U.S. Environmental Protection Agency (EPA) secondary treatment discharge limits of 30 mg/L for total suspended solids (TSS) and biological oxygen demand (BOD) the vast majority of the time, with only an occasional increase to the 30 to 40 mg/L range for perhaps 1 to 2 d. Loading rates were $\sim 0.25\text{ kg/m}^3\cdot\text{d}$ of TSS and BOD each, and the hydraulic retention time was 9 to 10 h. This performance was maintained in ambient cold weather tests ($\sim 12^\circ\text{C}$ water temperature), although the rate of solids accumulation in the bioreactor was higher in cold weather because of decreased biological activity, which normally converts solids to off-gas.

The primary mechanism for removal of TSS and BOD appears to be biophysical filtration. Approximately 20% of the influent carbon was converted to methane, while 30% remained in the bioreactor as sludge. The balance of the carbon was converted to CO_2 or remained in the liquid effluent as TSS and BOD/COD. Over half of the methane was dissolved in the effluent water; this methane could potentially be recovered along with the methane in the off-gas.

The average rate of accumulation of dry solids in the bioreactor was $\sim 150\text{ kg}/3800\text{ m}^3$ (million gal) of wastewater treated, which represents a 75 to 80% reduction in solids production compared to primary sedimentation and activated sludge or trickling filtration. The rate was slightly higher in cold weather and somewhat lower in warm weather. A simple material balance model was shown to predict the sludge accumulation using measurable influent and effluent parameters.

Gas production increased at higher loading rates with higher strength wastewater. Solids accumulation also increased, probably due in part to the high solids content of the feed, which was formulated by mixing primary clarifier underflow with the raw wastewater. Performance

of the ANFLOW process under these conditions is ambiguous, however, because the bioreactor was heavily loaded with accumulated solids when this test was run.

After ~2 years of operation, the pilot plant was decommissioned, and the site was returned to the City of Knoxville, as required by contractual agreements.

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1. INTRODUCTION

Recent development of the upflow anaerobic filter, the upflow anaerobic sludge blanket, and the attached-film expanded bed, along with a better understanding of the microbiology of anaerobic processes, has suggested that the use of anaerobic bioactivity for treating low-strength wastewater at temperatures below 20°C may be feasible. The fixed-film processes are especially attractive because the bacteria are retained on the packing material and not washed off in the effluent; therefore, mean cell residence times on the order of 100 d can be obtained. Also, the fixed-film systems have been postulated to be less susceptible to toxic materials because films exposed to these materials may slough off, leaving lower levels of film viable for continued wastewater treatment. A literature review for the anaerobic treatment of municipal and industrial wastewater in fixed-film reactors has been given by Henze et al.¹ Overviews of the application of anaerobic biotechnology for industrial wastewater treatment have been given by Speece² and Olthof and Oleszkiewicz.³

The development of anaerobic filter technology for the treatment of municipal wastewater has been pursued by Oak Ridge National Laboratory (ORNL) since 1976. A chronology of major activities conducted during the ANFLOW project is provided in Table 1.1. (ANFLOW is an acronym derived from the anaerobic, upflow nature of the process). The ANFLOW program was supported by the Division of Energy from Municipal Wastes, Office of Renewable Technology, U.S. Department of Energy (DOE) and the Office of Research and Development, Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency (EPA).

Basic studies conducted on ANFLOW columns at ORNL have been described by Griffith⁴ and Compere.⁵ Results of applied laboratory studies have been presented by Hines^{6,7} and Rivera.^{8,9} The process

Table 1.1. Chronology of major activities in the ANFLOW project

Fiscal Year	Activities
1976	• Laboratory studies on ANFLOW column start-up and operation
1977-1978	• Process feasibility studies with $19\text{-m}^3/\text{d}$ (5000-gpd) ANFLOW Pilot Plant in Oak Ridge, Tenn.
1979-1980	• Laboratory studies on heavy metal toxicity phenomena and on the conversion of organic nitrogen to ammonia in ANFLOW columns • Location of site and private sector partners for process development studies
1980-1981	• Plant design, bidding, site preparation, construction, shake-down, and start-up (August 1981) activities
1982	• ANFLOW process development studies with a $190\text{-m}^3/\text{d}$ (50,000-gpd) ANFLOW pilot plant in Knoxville, Tenn.
1983	• Cold-weather tests with Knoxville pilot plant^a • High-strength loading tests with Knoxville pilot plant
1984	• Plant decommissioning • Final reports

^aFunded by EPA; all other work funded by DOE.

feasibility work, based on a $19\text{-m}^3/\text{d}$ pilot plant and performed in Oak Ridge, Tennessee, has been described in detail by Genung and others.¹⁰⁻¹⁸ The design and start-up of the $190\text{-m}^3/\text{d}$ pilot plant used in the Knoxville process development studies has been described by Rivera et al.,¹⁹ who also provided a summary of the performance of that ANFLOW system during its first year of operation. Other studies involving economic analyses and related market assessment have been reported by Griffith²⁰ and the JBF Scientific Corporation.²¹ The economic study by Griffith²⁰ was prepared prior to the Oak Ridge pilot plant studies; the economic and market

studies by Davis et al.²² and JBF²¹ were prepared after the Oak Ridge pilot plant studies but prior to the studies conducted on the Knoxville pilot plant.

2. SUMMARY OF 190-m³/d ANFLOW PILOT PLANT FACILITY

The ANFLOW pilot plant is located adjacent to and obtains wastewater feed from the Loves Creek Wastewater Treatment Plant, which is situated in Knoxville, Tennessee. The Loves Creek plant is designed to process wastewaters to secondary treatment standards as established by the EPA. The solids that are separated and generated in the process are pumped to Knoxville's Kuwahee Sewage Treatment Plant, where they are further treated by anaerobic digestion.

A flow schematic of the Loves Creek plant is shown in Fig. 2.1. Raw sewage flows into the pumping station at the nominal rate of ~11,400 m³/d (3.0 mgd). It first passes through a comminuting bar screen in which any large entrained solids are ground to less than ~1.3-cm particle size. The comminuted sewage is next pumped to a grit chamber where sand, gravel, and other solid materials that settle are removed by sedimentation. The grit chamber serves to remove abrasive material and thereby protects the downstream mechanical equipment. Solids that settle out in the grit chamber are removed to a dumpster via a mechanical conveyor. The wastewater then passes to the primary settling tanks where a large fraction of the solids with specific gravities greater than that of water are settled out and materials such as oil and grease, which have a specific gravity less than water, are skimmed from the surface. The function of the primary settler is to greatly reduce the load on the downstream biological units. The solids and skimmings from the settler are removed to the pumping station for transport to the Kuwahee plant. Primary settler effluent is next routed to two trickling filters that operate in parallel. In the trickling filters the biological oxygen demand (BOD) is reduced by the action of aerobic microorganisms that are attached to the packing material (rocks) in the filter. The trickling filter effluent is next clarified in two parallel thickeners. The thickener overflow is then chlorinated and subsequently discharged to Loves Creek.

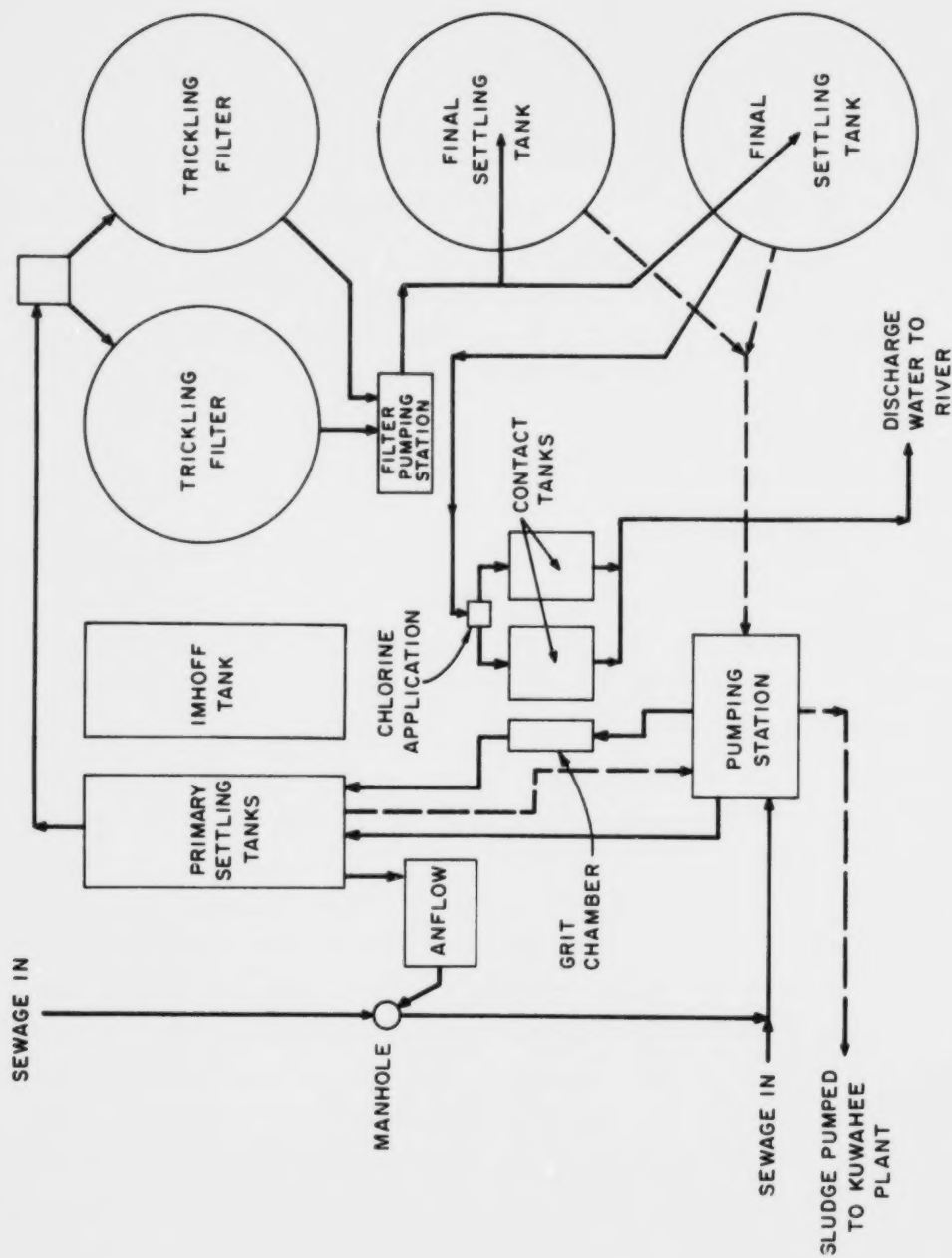


Fig. 2.1. Plan layout of Loves Creek Wastewater Treatment Plant -
Knoxville, Tennessee.

The thickener underflow is pumped, along with the primary settling tanks underflow, to the Kuwahee plant for anaerobic digestion.

As shown in Fig. 2.1, the feed take-off point for the ANFLOW system is located after pretreatment (bar screening and grit settling), but before primary clarification, on the Loves Creek system. The ANFLOW pilot plant was designed to process $\sim 190 \text{ m}^3/\text{d}$ (0.05 mgd) of municipal sewage. The flowsheet of the ANFLOW pilot plant is depicted in Figs. 2.2 and 2.3.

The ANFLOW bioreactor was basically a coned-bottom, mild-steel tank constructed to American Petroleum Institute (API) 620 Code Specifications. It was 4.9 m (16 ft) in diameter and 5.4 m (18 ft) high with a 3-m (10-ft)-high packed section. The internal surfaces were coated with Amercoat coal-tar epoxy paint. The entire system was mounted on truck scales to provide a continuous readout of its weight.

The 3-m section above the cone was packed with 3-in. polypropylene Pall rings manufactured by Glitsch, Inc., which were floated into place randomly. This material is relatively inexpensive, gives a high void fraction in the bioreactor, has an acceptably high packing surface area, and has an open structure to facilitate intermittent backwashing of solids from the bioreactor. Sampling ports were located at several axial and radial positions in the bioreactor. The gas headspace above the normal liquid volume was $\sim 7.5 \text{ m}^3$. The off-gas was monitored and safely vented through the roof. The incoming wastewater could be preheated to $\sim 25^\circ\text{C}$ in a vertical, double-pipe heat exchanger. Liquid effluent was recycled to the inlet of the Loves Creek plant.

3. ANFLOW PERFORMANCE SUMMARY

The ANFLOW bioreactor was inoculated with sewage sludge in August 1981. The first-year operation (start-up period) of the $190\text{-m}^3/\text{d}$ ANFLOW pilot plant has been summarized by Rivera et al.¹⁹ Throughout this period, the process consistently met the U.S. Environmental Protection Agency's (EPA's) requirements regarding permissible BOD and total suspended solids (TSS) levels in the effluent. The system operated with no significant problems.

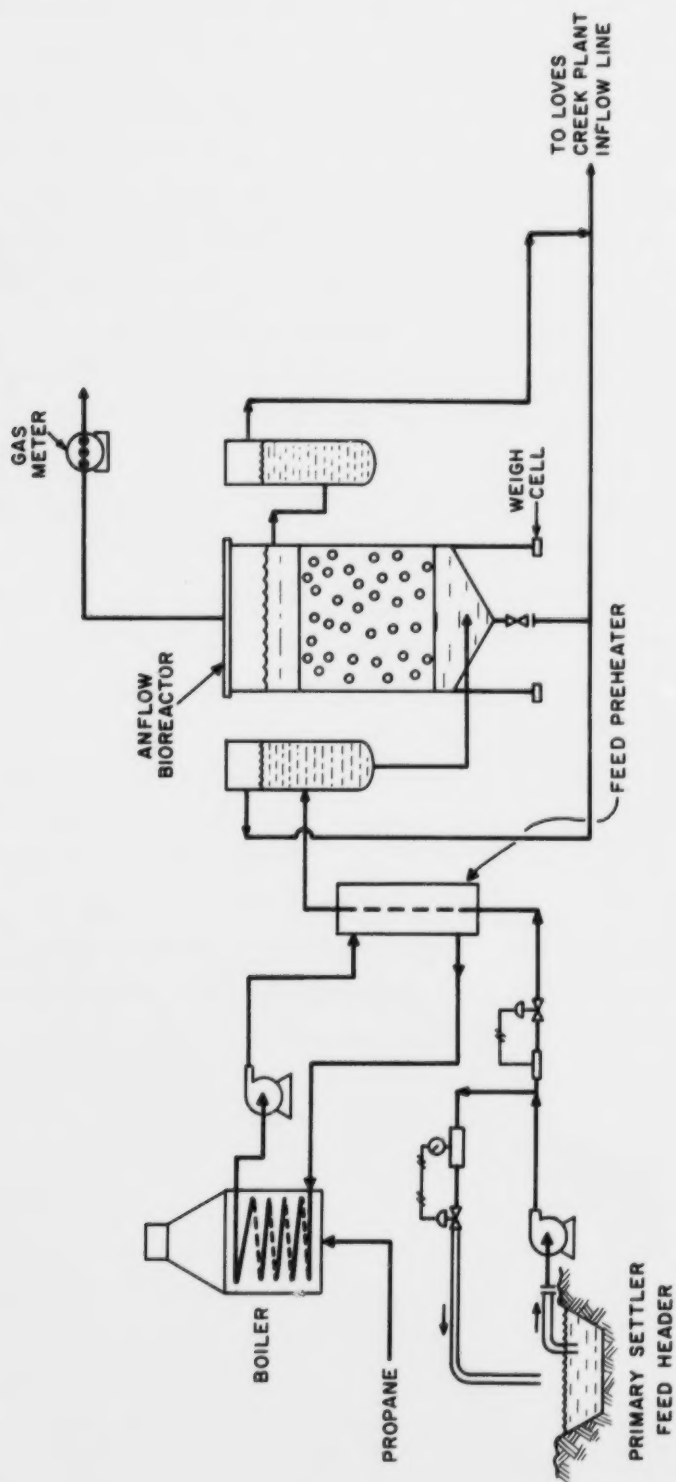
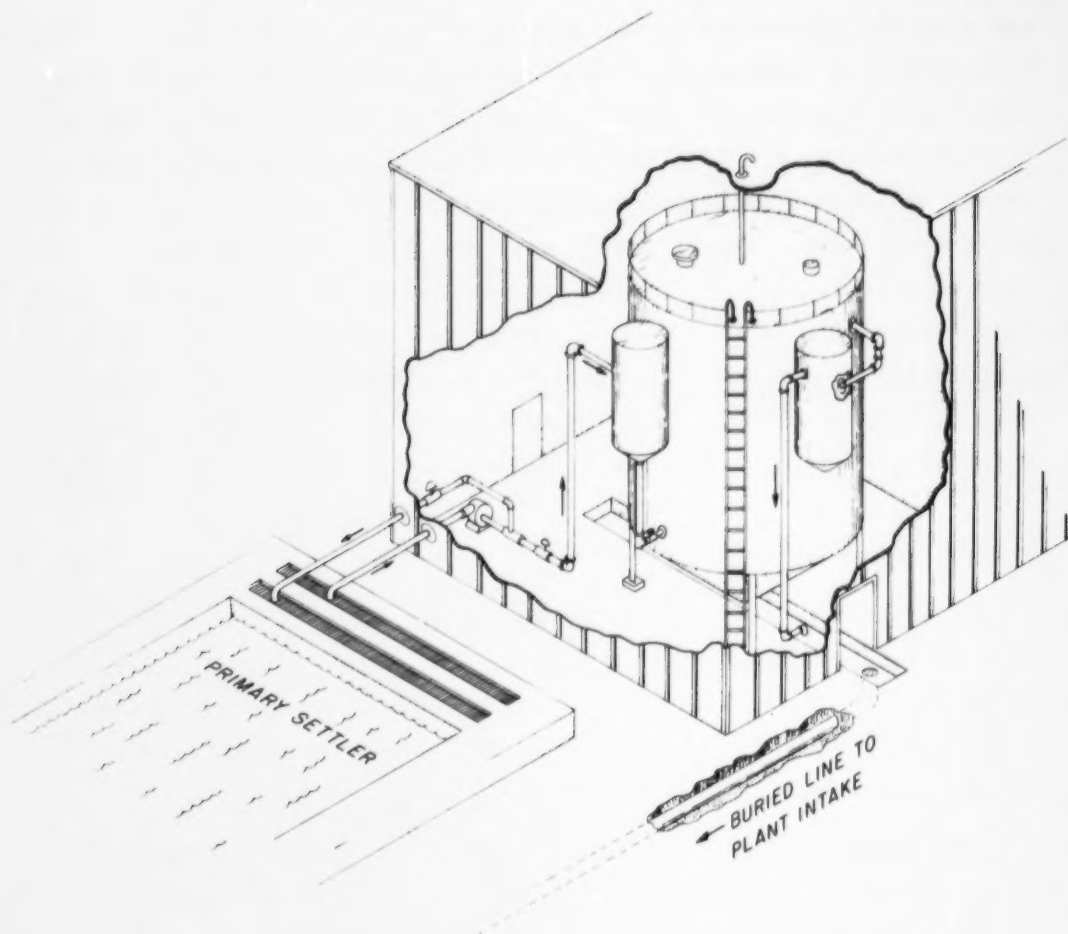


Fig. 2.2. ANFLOW 10-m³/d R&D pilot plant flowsheet.



ANFLOW 50,000-gpd R&D PILOT PLANT

Fig. 2.3. Pictorial representation of the ANFLOW pilot plant.

The present report summarizes the operation of the pilot plant from October 1, 1982 to October 20, 1983. During this period, the ANFLOW bioreactor was subjected to various operating conditions. The bioreactor was operated at ambient temperature from October 1, 1982 to March 16, 1983. This period is covered in terms of the bioreactor's performance under decreasing temperature (Sect. 3.1) and the bioreactor's performance during cold weather (Sect. 3.2). At the conclusion of the ambient temperature study, the feed preheater was turned on, and the column response to the spring and summer warm-up period was simulated. This phase of operation is discussed in Sect. 3.3. A high-strength wastewater study, in which primary clarifier underflow was added to the wastewater feed, is discussed in Sect. 3.4. A complete tabulation of the operating data from October 1982 through October 1983 is given in Appendixes A and B. Data for the earlier start-up period is given in ref. 19.

3.1 ANFLOW PERFORMANCE UNDER DECREASING TEMPERATURES

The operating period from October 1982 thru November 1982 (days 422 to 482) was termed the decreasing temperature period. During this period the operating temperature (Fig. 3.1) dropped from 21°C during the first of October to 16°C at the end of November. The average temperatures for October and November were 20 ± 1 and $18 \pm 1^\circ\text{C}$, respectively.

The feed flow rate (Fig. 3.2) during this period averaged 132 L/min. This corresponds to a hydraulic loading rate of $10.1 \text{ m}^3/\text{m}^2 \cdot \text{d}$ and a theoretical residence time of 9.5 h. The discussion of the other measured parameters is given in the following sections.

3.1.1 Influent and Effluent Characteristics

The influent pH was typically 7.2, and the effluent pH was typically 6.8 (Fig. 3.3). Daily influent and effluent TSS ranged from 30 to 100 mg/L and 5 to 20 mg/L, respectively (Fig. 3.4). Monthly average influent and effluent TSS values varied from 61 ± 30 to 91 ± 53 mg/L and 9 ± 5 to 11 ± 4 mg/L, respectively, with average reductions of 82 to 90%. Influent and effluent volatile suspended solids (VSS) are also shown in Fig. 3.5.

Daily chemical oxygen demand (COD) values (Fig. 3.6) ranged from 80 to 230 mg/L for the influent and 35 to 80 mg/L for the effluent. Influent monthly average values were 183 ± 85 mg/L for October and 135 ± 36 mg/L

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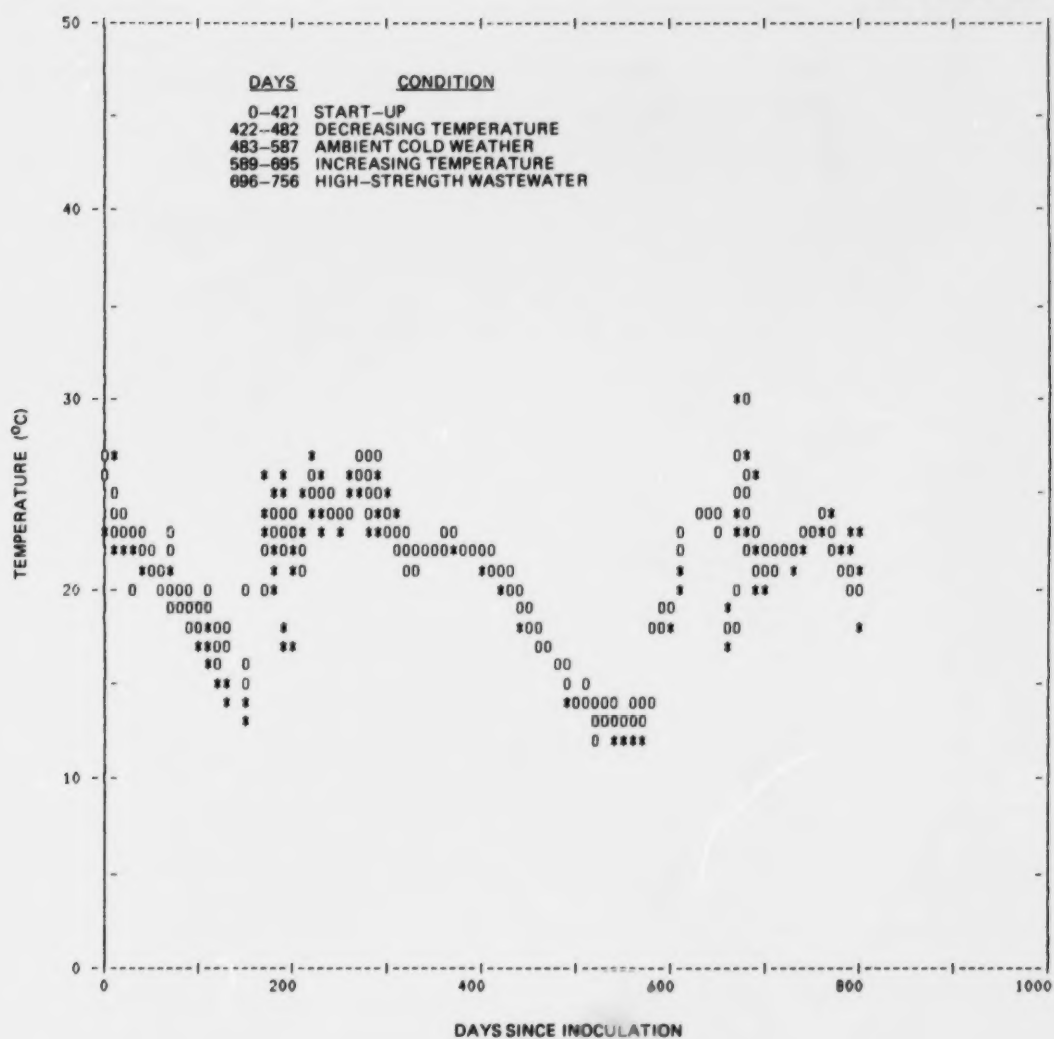


Fig. 3.1. Influent and effluent water temperatures.

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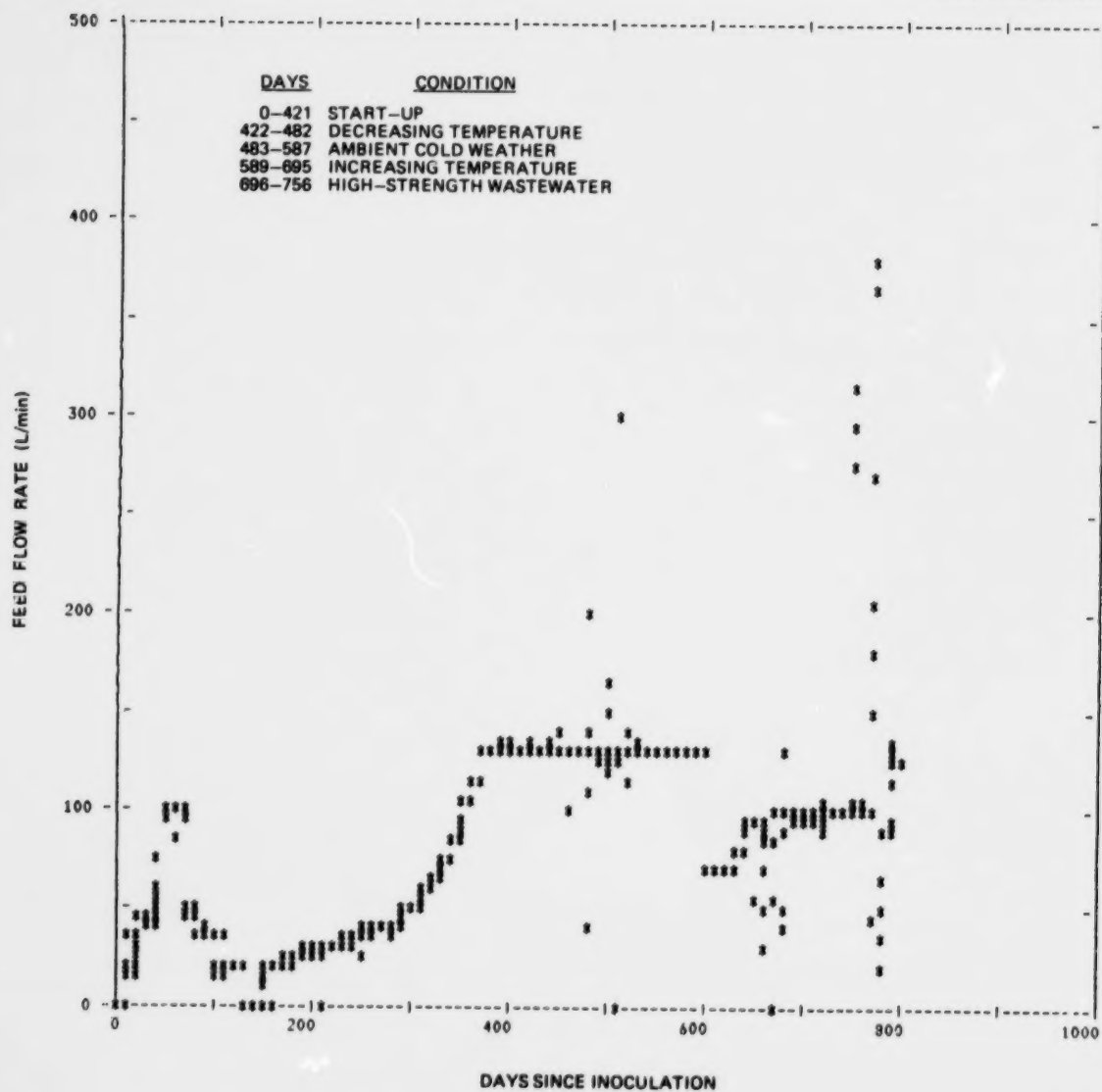


Fig. 3.2. Feed flow rate.

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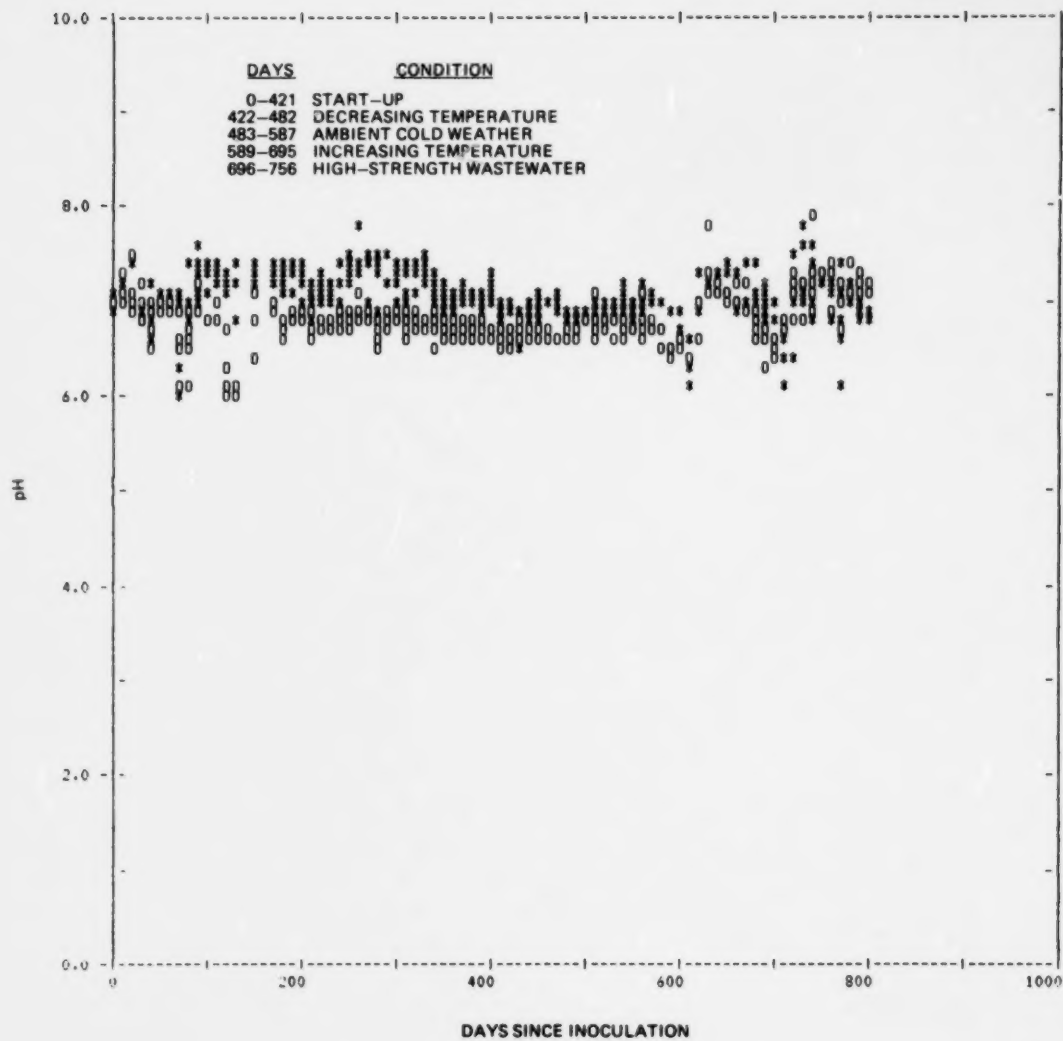


Fig. 3.3. Influent and effluent pH.

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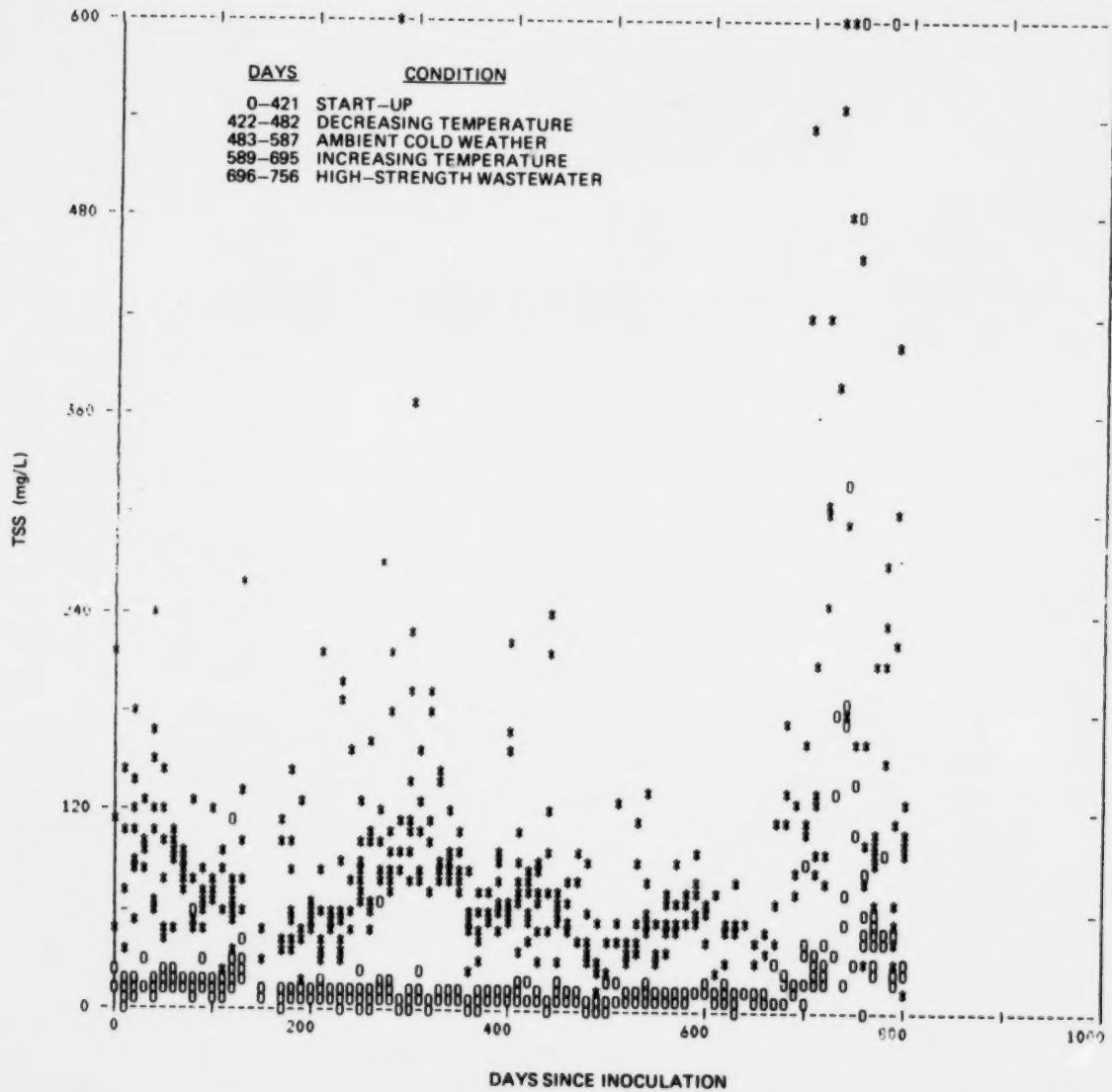


Fig. 3.4. Influent and effluent total suspended solids (TSS) concentrations.

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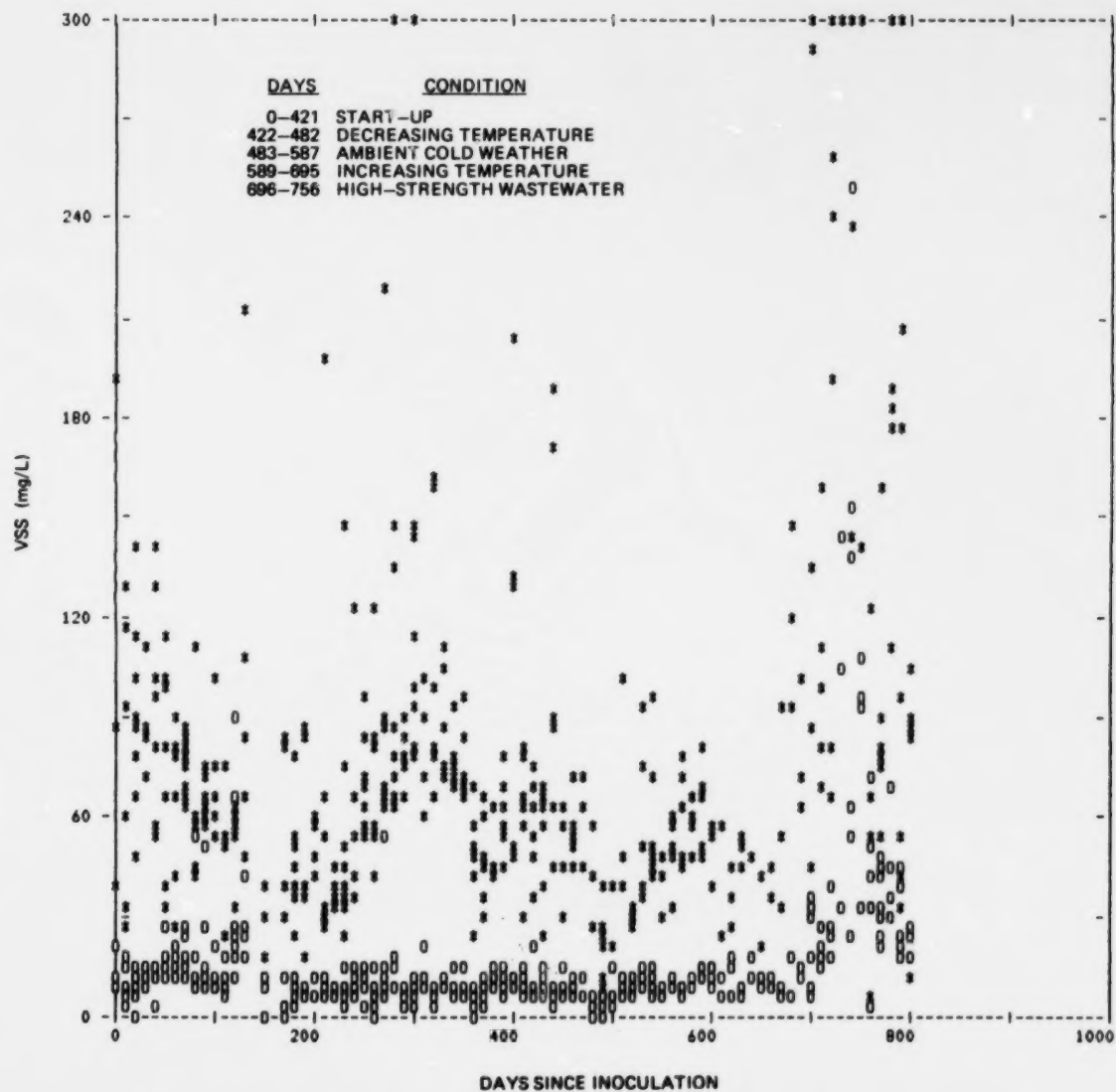


Fig. 3.5. Influent and effluent volatile suspended solids (VSS) concentrations.

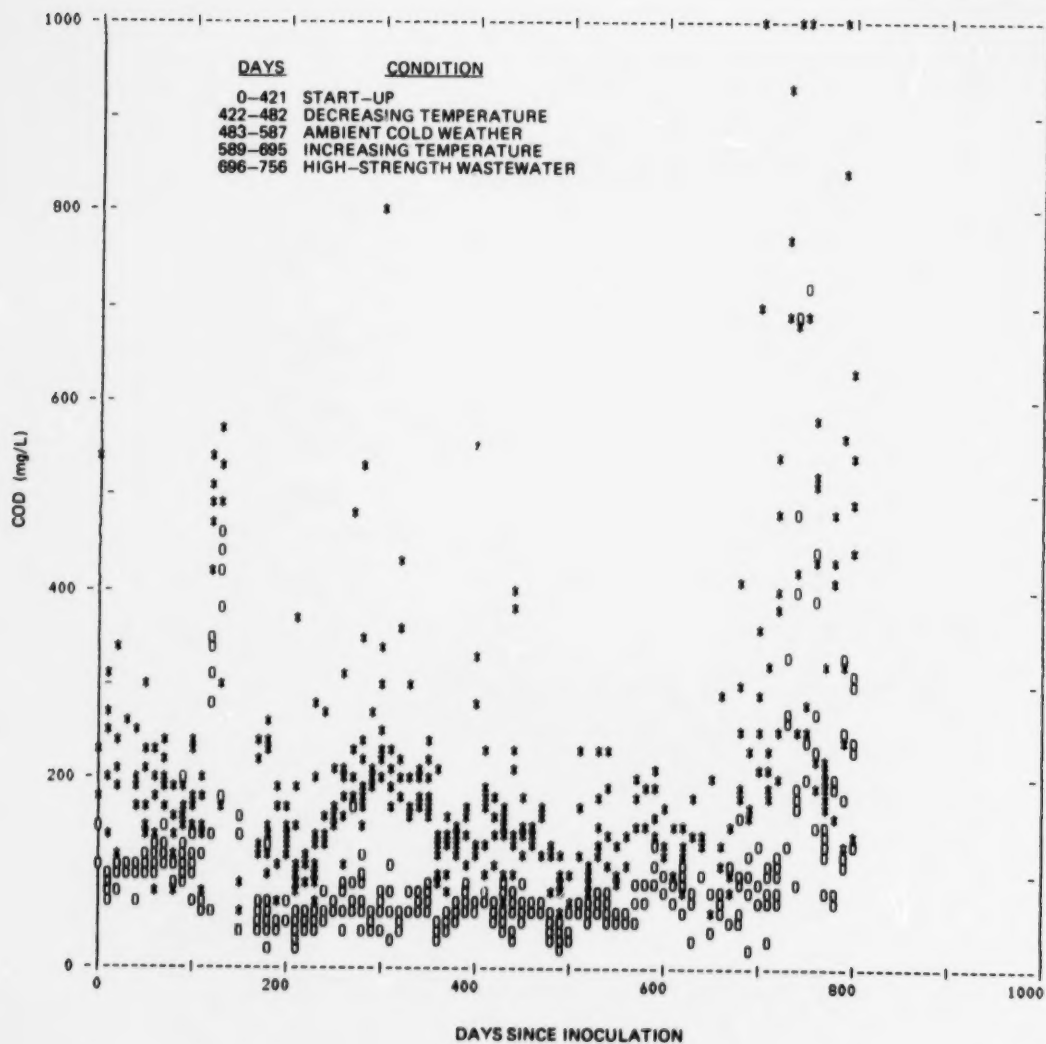


Fig. 3.6. Influent and effluent total chemical oxygen demand (COD) concentrations.

for November; effluent averages were 63 ± 18 mg/L and 65 ± 10 mg/L, respectively. Monthly average percent removals were 66 for October and 48 for November. Daily soluble COD values ranged from 25 to 80 mg/L for the influent and 25 to 60 mg/L for the effluent (Fig. 3.7). Monthly average values were 53 ± 19 and 49 ± 12 for the influent in October and November, respectively. Effluent average values were 44 ± 13 and 42 ± 7 . Average percent removals based on monthly average values were 17 and 14, respectively. The monthly BOD averages were 106 ± 38 and 84 ± 29 for the influent and 25 ± 5 and 30 ± 6 for the effluent with average reductions of 76 and 64 percent, respectively (Fig. 3.8).

3.1.2 Gas Production

The gas production rate decreased from $1 \text{ m}^3/\text{d}$ during the first of October to $<0.1 \text{ m}^3/\text{d}$ at the end of November (Fig. 3.9, days 422 to 482). Methane concentration decreased from 76% to 68% over the same period (Fig. 3.10). The off-gas typically contains ~2% carbon dioxide and the balance as nitrogen (dry basis). Most of the CO_2 produced with the methane dissolves in the liquid, while the N_2 is stripped from the influent wastewater. The measured amount of methane lost in the liquid effluent was $\sim 2 \text{ m}^3/\text{d}$ (see ref. 19 for technique).

3.2 ANFLOW PERFORMANCE DURING COLD WEATHER

The cold-weather operation is defined as the period from December 1, 1982 to March 16, 1983 (days 483 to 588), the seasonal winter months for the Knoxville area.

3.2.1 Feed Flow Rate

The ANFLOW column was operated at the design flow rate of $190 \text{ m}^3/\text{d}$ ($\sim 50,000$ gpd) during the cold-weather study (Fig. 3.2). This corresponds to a hydraulic loading rate of $10.2 \text{ m}^3/\text{m}^2 \cdot \text{d}$ and a theoretical residence time of 9.4 h. The column was operated at a constant flow rate so that the effect of temperature on column performance could be evaluated, independent of the effect of hydraulic loading rate.

3.2.2 Influent and Effluent Characteristics

The influent and effluent streams were routinely monitored for pH, temperature, TSS, VSS, BOD, and COD. Periodically, phosphates, sulfate,

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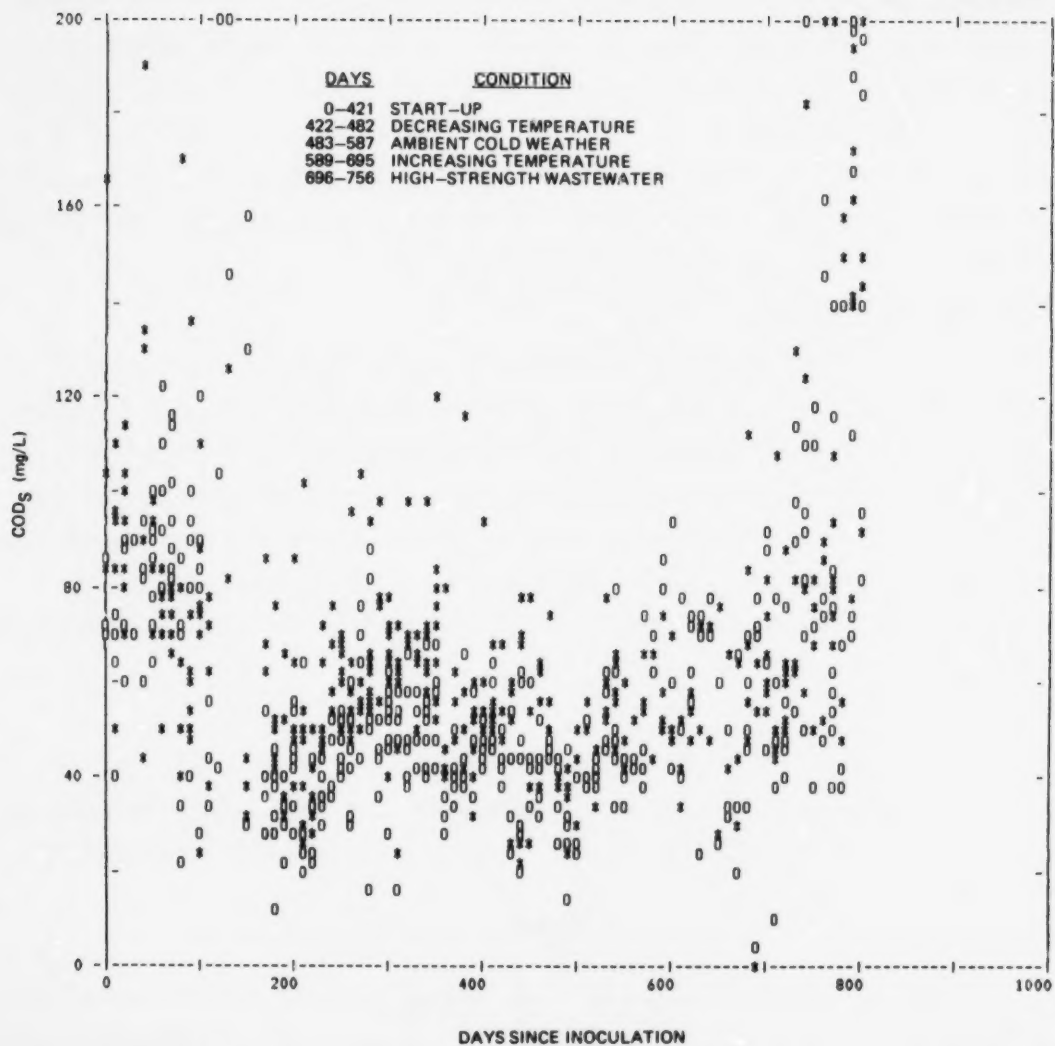


Fig. 3.7. Influent and effluent soluble chemical oxygen demand (COD_s) concentrations.

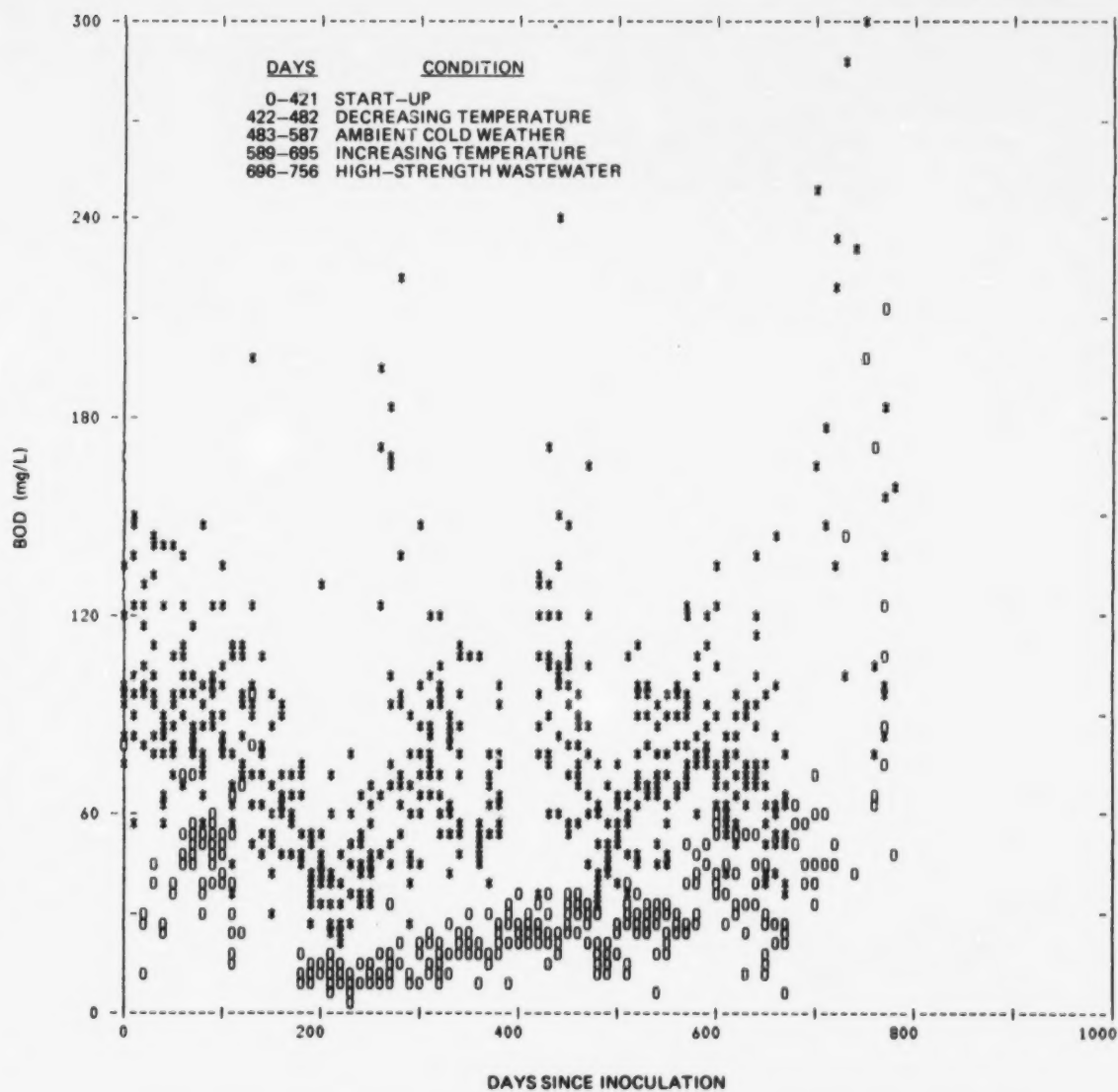


Fig. 3.8. Influent and effluent biological oxygen demand (BOD) concentrations.

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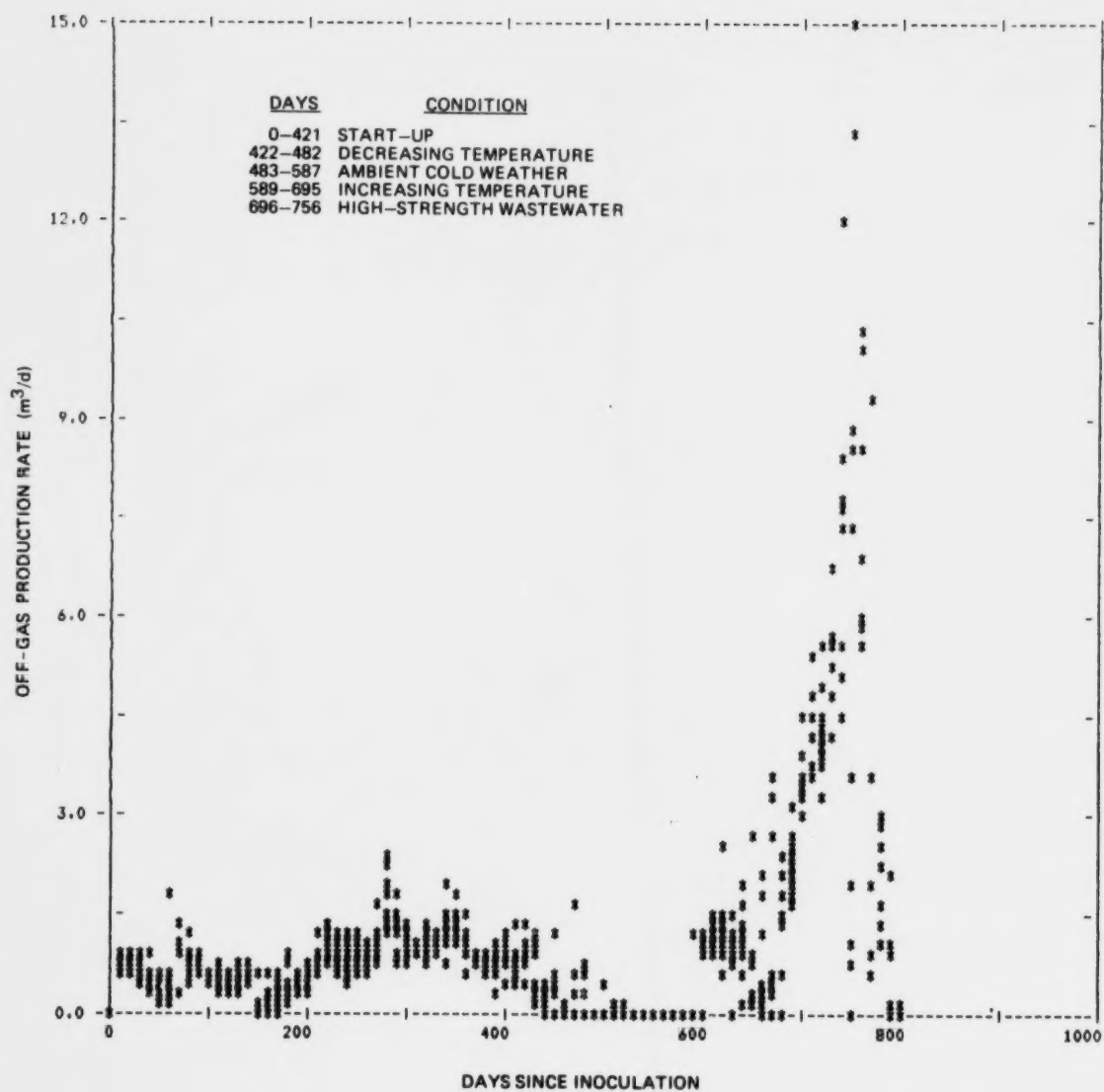


Fig. 3.9. Off-gas production rate.

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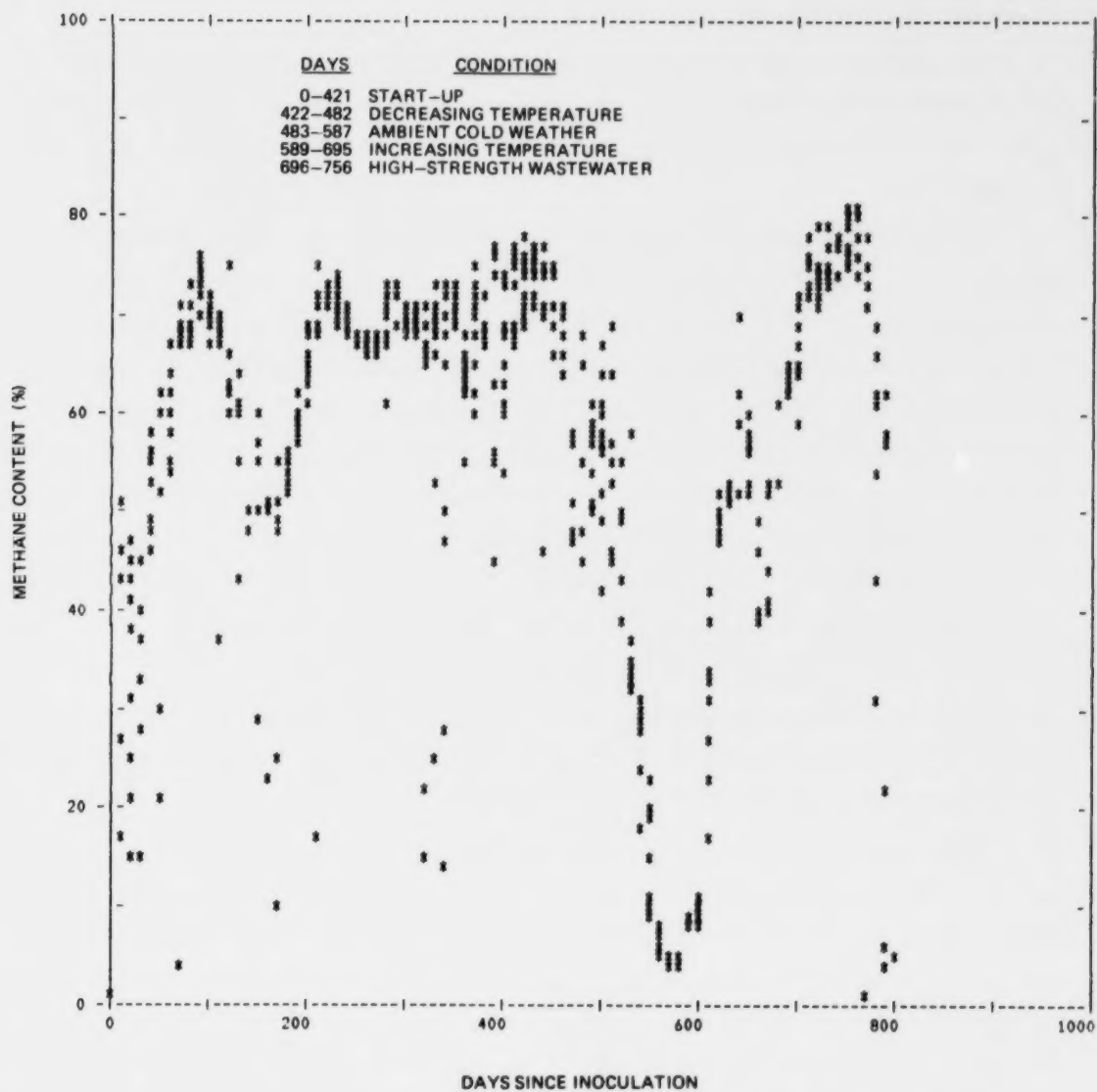


Fig. 3.10. Methane content of the off-gas.

sulfide, and volatile acids were analyzed to provide additional information on column performance.

The following performance was observed during the cold-weather study (12/1/82 to 3/16/83, or days 483 to 588).

The influent and effluent pH values ranged from 6.8 to 7.2 and 6.6 to 7.0, respectively (Fig. 3.3). The operating pH of the column was, therefore, within the acceptable pH range of 6.5 to 7.8 for anaerobic bioactivity.

Influent and effluent temperatures during the cold-weather study ranged from 12 to 15°C (Fig. 3.1). These temperatures were 10°C lower than the temperatures observed during the summer and 20°C lower than the optimum temperature for mesophilic anaerobic bioactivity. Anaerobic systems are traditionally considered inadequate for processing low-strength wastewater and at temperatures below 20°C. However, the biofiltration aspect of the ANFLOW column, coupled with the characteristics of the wastewater, resulted in acceptable effluent BOD and TSS concentrations (<30 mg/L each; see Figs. 3.4 and 3.8) during the cold-weather operation.

The daily TSS concentration in the influent and effluent varied from 30 to 130 mg/L, and 8 to 18 mg/L, respectively (Fig. 3.4). The effluent TSS was not affected by the cold-weather operation and was consistently <30 mg/L. Daily influent and effluent VSS ranged from ~25 to 80 mg/L and 8 to 16 mg/L, respectively (Fig. 3.5).

To monitor the organic removal and biochemical activity of the system, COD and BOD analyses were done on the influent and effluent streams. The daily influent and effluent total COD randomly varied from 75 to 200 mg/L and 50 to 90 mg/L, respectively (Fig. 3.6). Soluble COD ranged from 25 to 80 mg/L for the influent and 14 to 80 mg/L for the effluent (Fig. 3.7). The influent soluble COD was ~37% of the influent total COD.

Daily influent and effluent BOD (Fig. 3.8) ranged from 50 to 105 mg/L and 10 to 40 mg/L, respectively. Monthly average effluent BOD ranged from 20 to 31 mg/L, and were, for the most part, <30 mg/L.

3.2.3 Special Analyses

Periodically, analyses for total phosphates, orthophosphates, total nitrogen (TKN), $\text{NH}_3\text{-N}$, sulfates, sulfides, and volatile acids were done on influent and effluent samples.

The average total phosphates and orthophosphates concentrations were 2.5 and 2.0 mg/L (3 samples) in the influent and 3.0 and 2.0 mg/L (4 samples) in the effluent. Influent and effluent TKN averaged 7.8 and 9.0 mg of N/L (3 samples each), while $\text{NH}_3\text{-N}$ averaged 7.0 and 7.8 mg/L (4 samples each), respectively. This suggested that <15% of the TKN was organic nitrogen.

During the cold-weather period, the influent and effluent volatile acids concentrations were <1 mg/L. These data, along with the fact that very little off-gas was produced during this period, indicated a substantial decrease in anaerobic bioactivity in the ANFLOW column during the cold-weather period.

Daily influent and effluent sulfate concentrations averaged 37 and 26 mg/L, respectively (4 samples). Sulfide concentrations were 0 and 6 mg/L for the influent and effluent streams. These data correspond to a sulfate reduction and sulfide production rate of ~ 1 kg/d, or $0.013 \text{ kg/m}^3\cdot\text{d}$, as sulfide. The concentration of sulfide in the liquid effluent was well below toxic levels (e.g., >100 mg/L) that have been known to inhibit methanogenesis.²

3.2.4 Axial Profile Sampling

The ANFLOW column was periodically sampled at levels of 0, 1.2, and 2.4 m (0, 4, and 8 ft) from the bottom of the packed section. The results are shown in Table 3.1. Total suspended solids and VSS concentrations were reduced from 46 to 17 mg/L (39% reduction) and 34 to 7 mg/L (79% reduction), respectively, through the packed section. Total COD and BOD concentrations were reduced by 43 and 63%, respectively. The data also showed some soluble organic reduction in the packed section as indicated by 35 and 23% reduction in soluble total organic carbon (TOC) and soluble COD concentrations, respectively. The data indicate that removal of total COD and TSS is greater in the lower portion of the packed section than in the upper portion (see Fig. 3.11).

The accumulation of appreciable amounts of volatile acids in the reactor was not observed as acetic acid concentrations at all points in the column were <1 mg/L, and influent and effluent pH values were essentially the same.

Table 3.1. Profile data for various parameter concentrations in ANFLOW (cold-weather period)

Height above bottom of packing (m)	COD (mg/L)	Soluble COD (mg/L)	TOC (mg/L)	Soluble TOC (mg/L)	TSS (mg/L)	VSS (mg/L)	Acetic acid (mg/L)
<u>14°C</u>							
0	115	57	40	20	46	34	<1
1.2	70	50	23	17	16	15	<1
2.4	66	44	15	13	17	7	<1

3.2.5 Gas Production

The off-gas production rate was reduced from $\sim 1 \text{ m}^3/\text{d}$ ($0.013 \text{ m}^3/\text{m}^3 \cdot \text{d}$) during the 22°C operating period to $<0.025 \text{ m}^3/\text{d}$ ($3 \times 10^{-4} \text{ m}^3/\text{m}^3 \cdot \text{d}$) during the cold-weather study (13°C). Similarly, the methane concentration in the vapor space of the column decreased from 70 to 3%. Figures 3.9 and 3.10 show the trend of the off-gas production rate and the methane concentration. The amount of dissolved methane in the liquid effluent decreased from $2 \text{ m}^3/\text{d}$ to $\sim 0.4 \text{ m}^3/\text{d}$.

Off-gas production rate as a function of temperature (monthly averages) is shown in Fig. 3.12 for the entire 2-year period of operation. There is considerable scatter in this plot because the off-gas rate is a function of other parameters in addition to temperature, but a clear dependence on temperature is seen. (Gas production during the high-strength wastewater tests described later are not shown in Fig. 3.12.).

3.2.6 Evaluation of the ANFLOW Process During Cold-Weather Operation

3.2.6.1 Reduction in TSS

The removal of TSS by the ANFLOW column during cold-weather operation as a function of TSS loading is shown in Fig. 3.13. By linear least squares analysis, the data were adequately modeled by the simple linear equation:

$$RR_{TSS} = 0.93 LR_{TSS} - 0.02, \quad (1)$$

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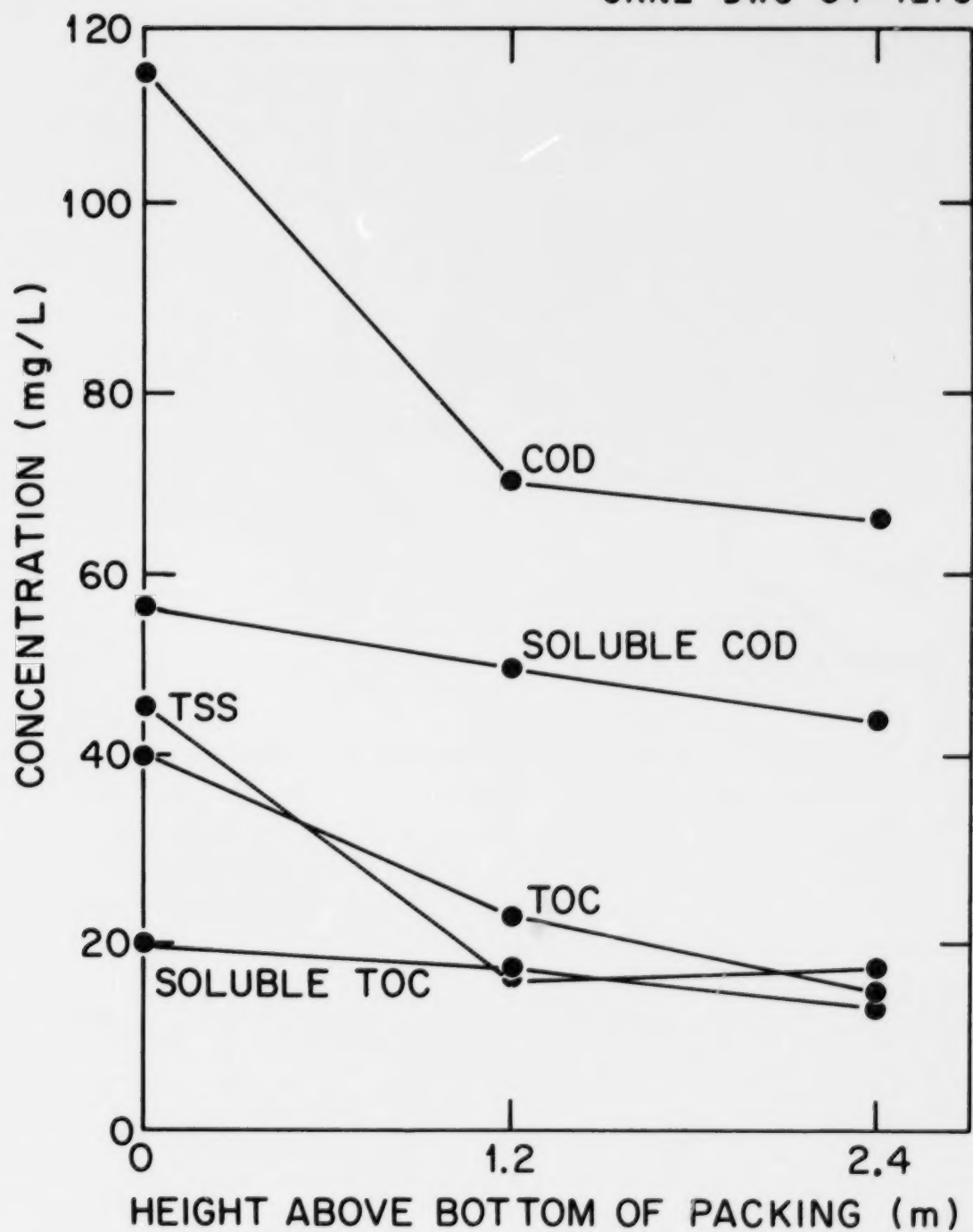


Fig. 3.11. Concentrations of solids and soluble species at several positions in the packed section of the column.

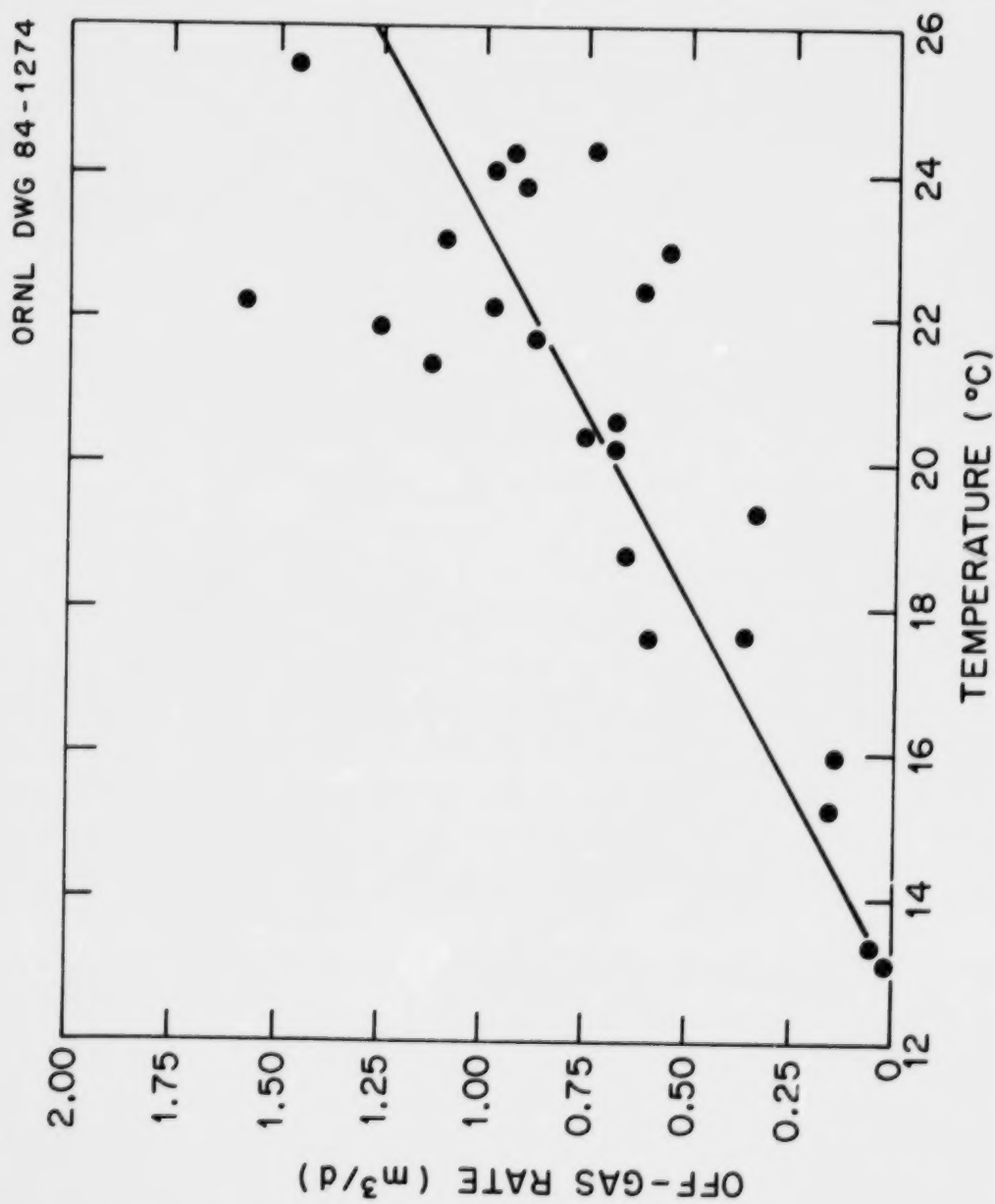


Fig. 3.12. Temperature dependence of the off-gas rate.

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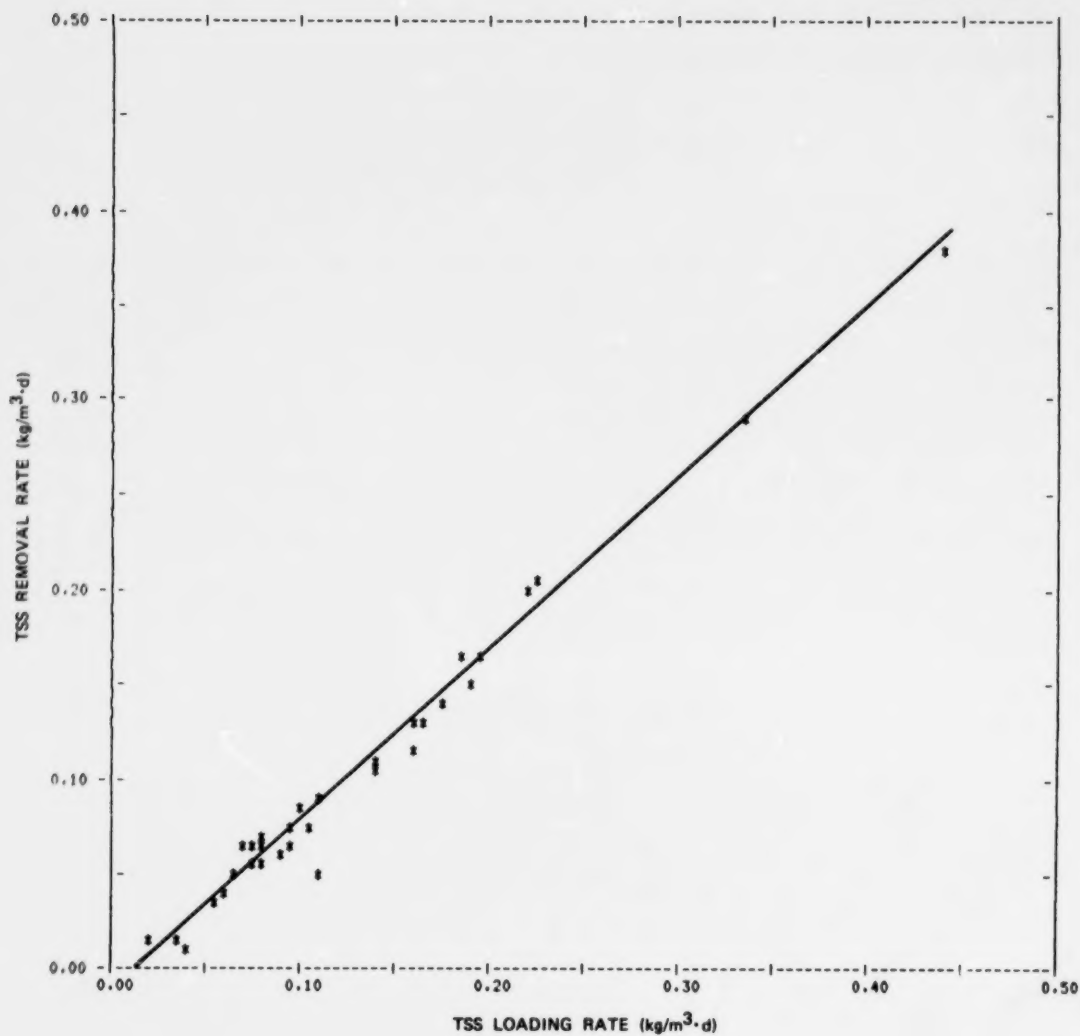


Fig. 3.13. TSS loading and removal rates during the cold-weather period.

where

RR_{TSS} = TSS removal rate, $\text{kg/m}^3 \cdot \text{d}$,

LR_{TSS} = TSS loading rate, $\text{kg/m}^3 \cdot \text{d}$.

By rearranging this equation, it can be shown that the TSS fractional removal, f_{TSS} , can be expressed as

$$f_{TSS} = \frac{RR_{TSS}}{LR_{TSS}} = 0.93 - \frac{0.02}{LR_{TSS}} .$$

LR_{TSS} ranged from $0.08 \text{ kg/m}^3 \cdot \text{d}$ to $0.33 \text{ kg/m}^3 \cdot \text{d}$, and calculated f_{TSS} had values from 0.68 to 0.87. The average percent removal, based on monthly average influent and effluent values, was 80.

3.2.6.2 Reduction in COD and BOD

Total COD and total BOD removals were also correlated with their respective loading rates (Figs. 3.14 and 3.15) and were found to be adequately modeled by the following simple linear equations:

$$RR_{COD} = 0.75 LR_{COD} - 0.08 , \text{ and} \quad (2)$$

$$RR_{BOD} = 0.81 LR_{BOD} - 0.04 . \quad (3)$$

The fractional removals, f_{COD} and f_{BOD} , are given by

$$f_{COD} = 0.75 - \frac{0.08}{LR_{COD}} , \text{ and} \quad (4)$$

$$f_{BOD} = 0.81 - \frac{0.07}{LR_{BOD}} . \quad (5)$$

The COD and BOD loading rates ranged from 0.19 to $0.51 \text{ kg/m}^3 \cdot \text{d}$ and 0.13 to $0.27 \text{ kg/m}^3 \cdot \text{d}$. Values of 0.33 to 0.59 and 0.50 to 0.66 are, therefore, obtained for f_{COD} and f_{BOD} , respectively. The average COD and BOD percent removals, based on monthly average influent and effluent values, were 52 and 63%, respectively.

Soluble COD loading-vs-removal rate data could not be represented by a linear model (Fig. 3.16). However, based on average influent and

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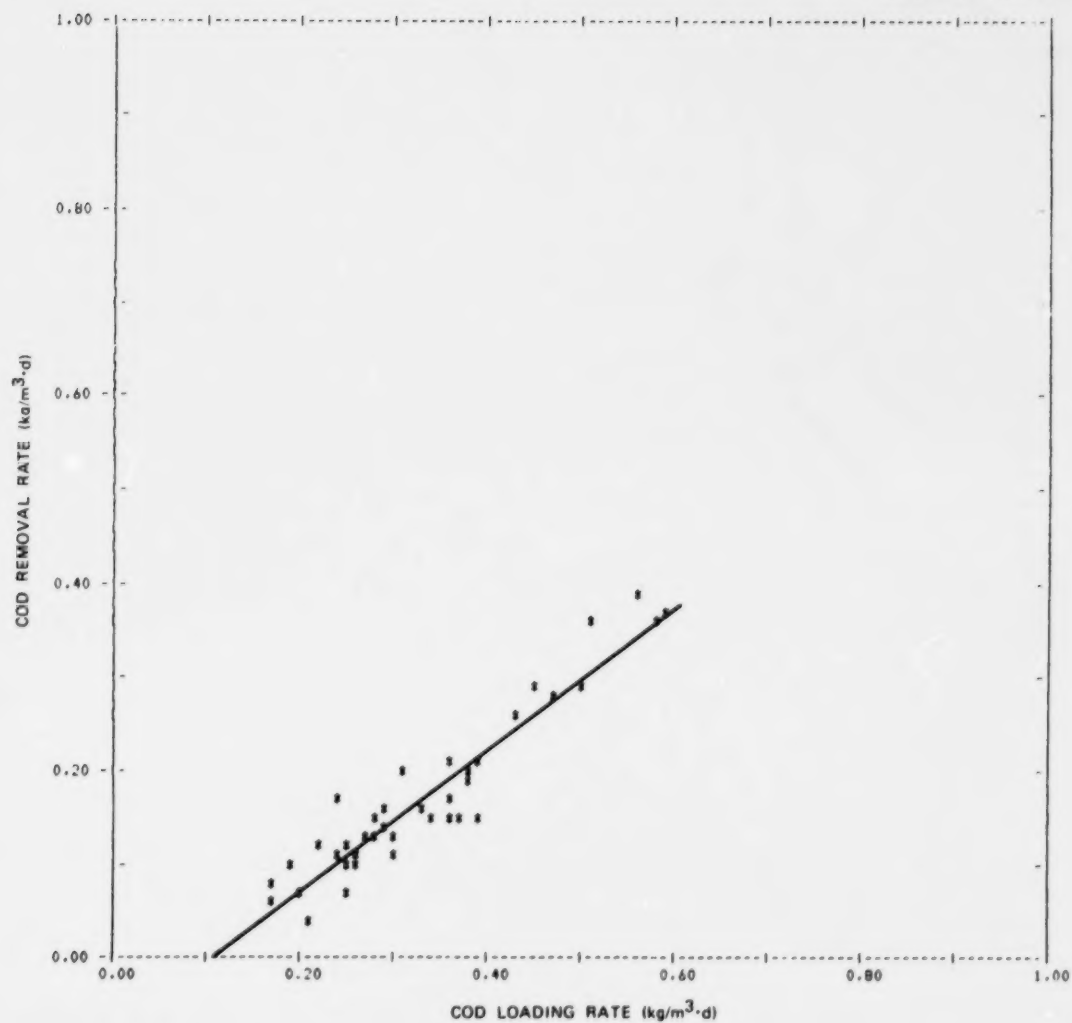


Fig. 3.14. COD loading and removal rates during the cold-weather period.

ORNL DWG 84 1277

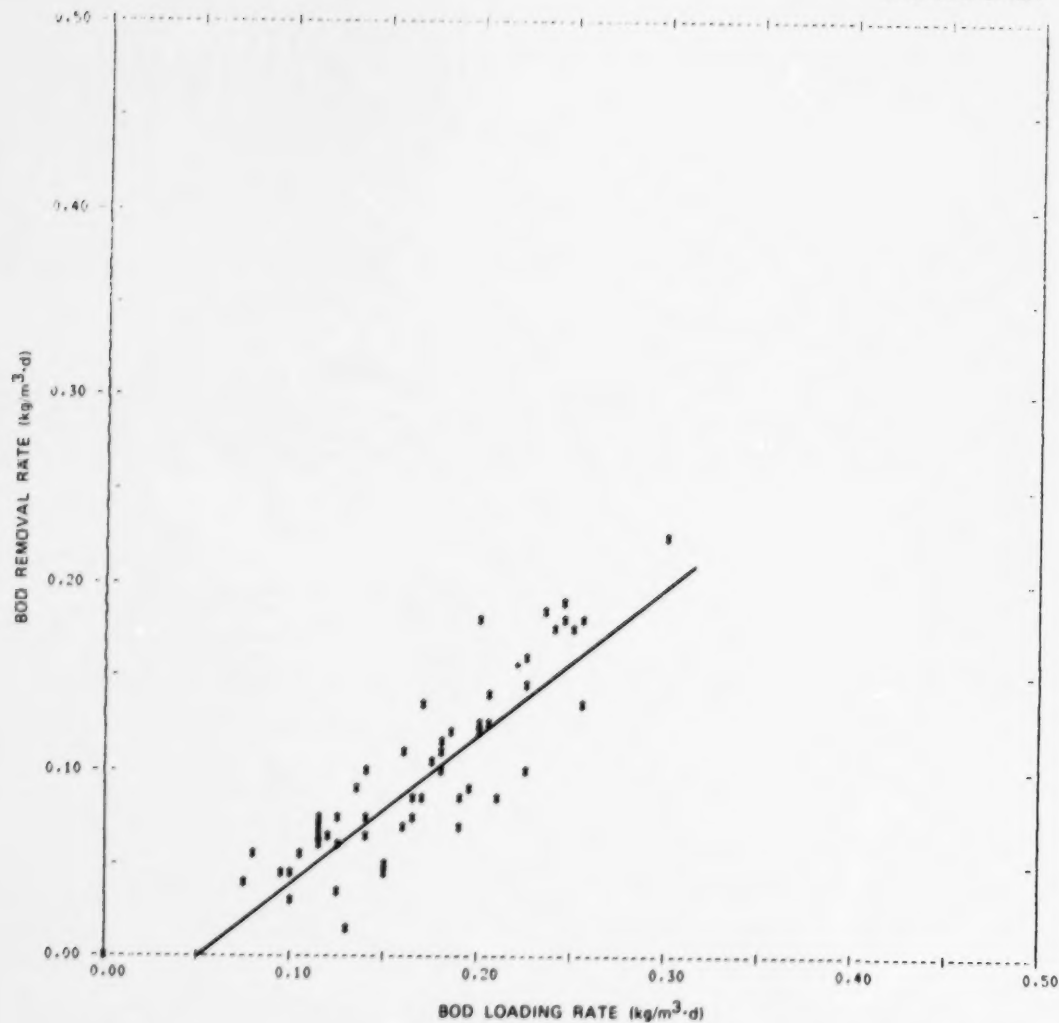


Fig. 3.15. BOD loading and removal rates during the cold-weather period.

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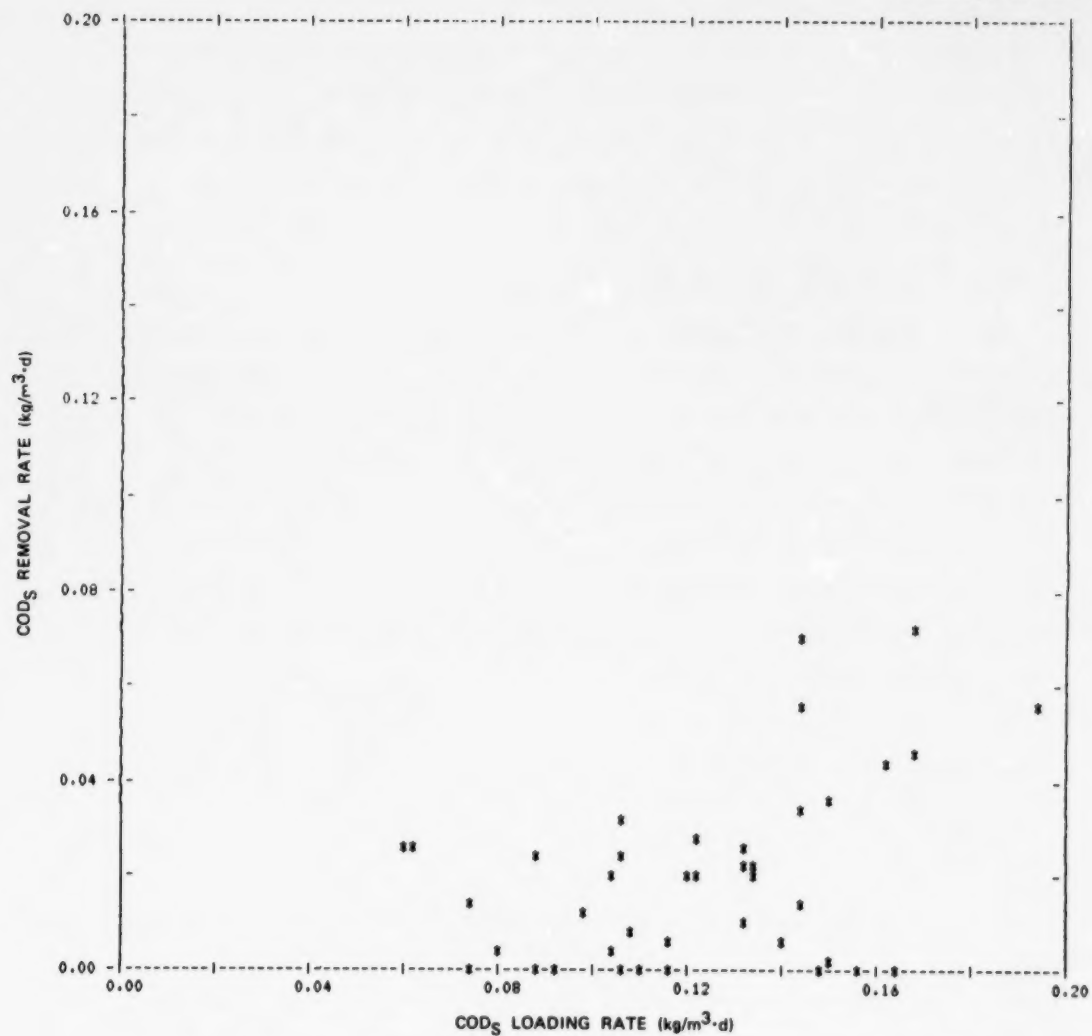


Fig. 3.16. Soluble COD loading and removal rates during cold-weather period.

effluent soluble COD values, ~9 to 18% of influent soluble COD was removed during the cold-weather period. The small reduction in soluble COD, coupled with the fact that only 37% of the total COD was soluble COD, indicates that most of the total COD removed was attributable to biofiltration and sedimentation during this period. Lettinga et al.²³ reported 50 to 75% reduction in soluble COD for the treatment of domestic wastewater with an upflow anaerobic sludge blanket reactor at an operating temperature of 10°C and influent COD levels of 400 to 500 mg/L.

3.2.6.3 Anaerobic Biological Activity

The methane production and volatile acid production are good indicators of the anaerobic behavior in the ANFLOW column. Methane production rate during steady-state operation can be accurately determined by the methane lost in the off-gas plus the amount lost in the liquid effluent. However, because of unsteady-state methane concentration in the vapor space during the period from January 1 to March 16, 1983, the methane production rate had to be corrected for the methane removed from the vapor space in the ANFLOW column. The following method was used in calculating the methane production rate:

$$\begin{array}{ccccccc} \text{methane} & & \text{methane lost} & & \text{methane} & & \text{methane removed} \\ \text{production} & = & \text{in liquid} & + & \text{lost in} & - & \text{from the vapor} \\ \text{rate} & & \text{effluent} & & \text{off-gas} & & \text{space} \end{array}$$

Dissolved methane analyses indicated that the liquid effluent was typically 50% saturated with methane. The average rate of methane lost in the liquid effluent and the off-gas during this period was 400 L/d and 10 L/d, respectively. Methane was removed from the vapor space at an average rate of 40 L/d as determined from the change in methane content of the off-gas over the cold-weather period. Therefore, the methane production rate averaged 370 L/d (5 L/m³·d). This suggested that there was some anaerobic activity at temperatures as low as 13°C, with methane yield coefficients of 28 L CH₄/kg COD removed and 50 L CH₄/kg VSS removed.

The accumulation of volatile acids and soluble organics in the reactor was not observed during the cold-weather period. This suggests that

the rate of hydrolysis and the rate of conversion to organic acid were the rate-limiting steps. Alternatively, the volatile acids and soluble organics may have washed out before they could be converted to methane.

3.2.6.4 Sludge Accumulation

The amount of sludge in the column was estimated by a computer program based on the material balance model shown in Fig. 3.17 and the measured change in weight of the ANFLOW column. The ANFLOW sludge program is based on a mass balance of the following form:

$$\begin{aligned} \text{rate of TSS accumulation (kg/d)} &= \text{rate of VSS in (kg/d)} - \text{rate of VSS out (kg/d)} + \text{rate of VSS production (kg/d)} \\ &\quad - \text{rate of VSS destruction (kg/d)} + \text{rate of IS in (kg/d)} - \text{rate of IS out (kg/d)}. \end{aligned}$$

In terms of measurable or otherwise known parameters, this equation is:

$$\begin{aligned} \frac{dm}{dt} &= Q_{in}[VSS]_{in} - Q_{out}[VSS]_{out} + (Q_{in}[COD_s]_{in} - Q_{out}[COD_s]_{out})/\beta_1 \\ &\quad - G/\beta_1\beta_2 + Q_{in}[IS]_{in} - Q_{out}[IS]_{out}, \end{aligned} \quad (6)$$

where

- m = total mass of solids in bioreactor, kg;
- $Q_{in} = Q_{out}$ = volumetric flow rate of feed, L/d;
- $[VSS]$ = VSS concentration, kg/L;
- $[COD_s]$ = soluble COD concentration, kg/L;
- β_1 = kg COD/kg VSS conversion factor, = 1.63;
- G = total methane production rate, L/d;
- β_2 = ratio of methane produced (L) to COD destroyed (kg)
= 350 L/kg;
- $[IS]$ = $[TSS] - [VSS]$ = inert solids concentration, kg/L.

Note that β_2 is simply a stoichiometric coefficient. The value of β_1 was estimated from experimental insoluble COD and VSS data for influent and effluent water.

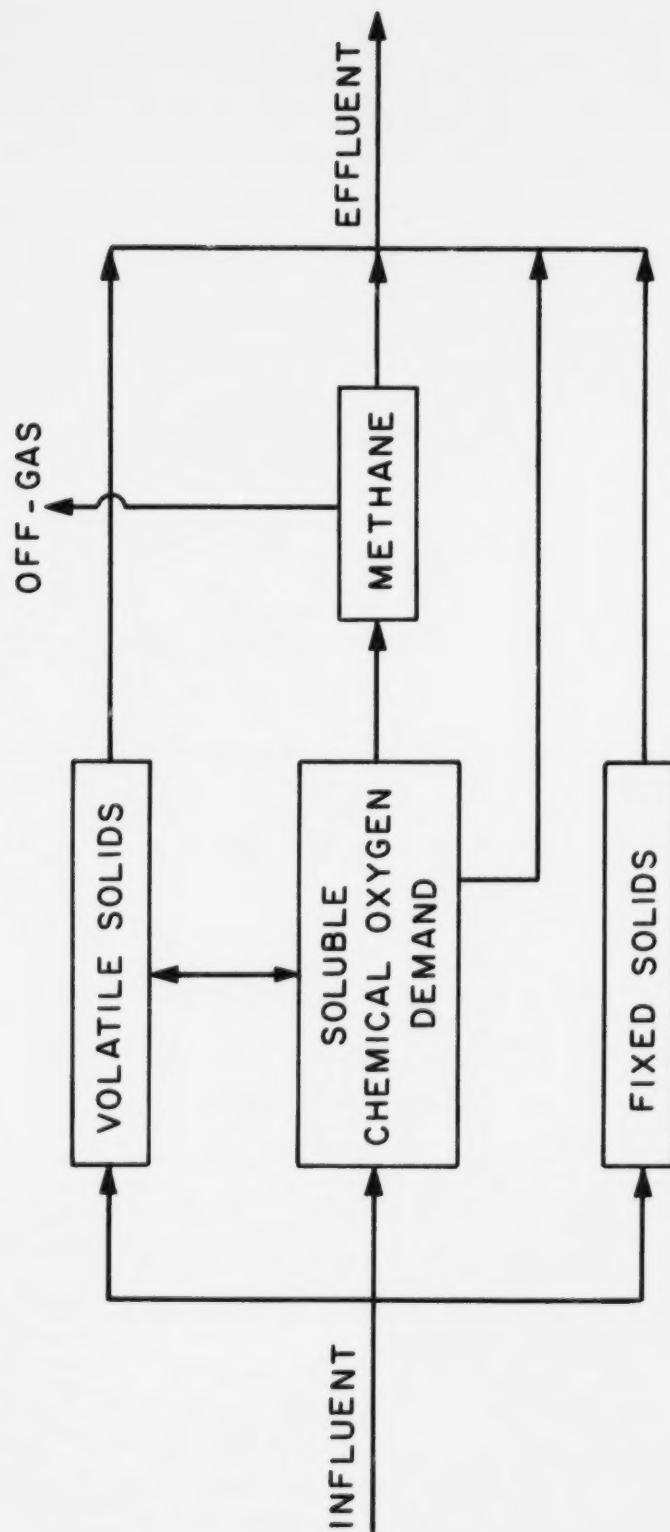


Fig. 3.17. Material balance model.

Another important variable is the fractional saturation, f , of methane in the liquid effluent. Dissolved methane analyses indicated that the liquid effluent was typically 50% saturated with methane, so $f = 0.5$ was used to determine the total methane production rate, G .

The total inventory of solids in the bioreactor is shown in Fig. 3.18. According to the model, ~850 kg of dry solids, or 170 kg solids/3800 m³ wastewater treated, accumulated in the column during the cold-weather period (days 483 to 588). Figure 3.18 also shows the solids accumulation as determined by the measured change in bioreactor weight. The following assumptions were used in converting bioreactor weight to the mass of solids in the reactor:

1. The total volume occupied by the liquid and solids is constant.
2. The densities of the water, volatile solids, and dry inert solid have constant values of 1.0, 1.0, and 2.5 g/mL, respectively.

The following equation was used to convert measured changes in bioreactor weight to the mass of accumulated solids:

$$m = \frac{\rho_s}{\rho_s - \rho_L} \Delta W_{\text{bioreactor}}, \quad (7)$$

where

ρ_s = density of solids, g/mL,

ρ_L = density of water, g/mL,

$\Delta W_{\text{bioreactor}}$ = change in bioreactor weight, kg.

Figure 3.18 shows excellent agreement between the model and the experimental data over the entire operating period of ~750 d.

3.3 ANFLOW PERFORMANCE UNDER INCREASING TEMPERATURES

To simulate increasing operating temperatures during the spring and summer, the feed preheater was started on March 16, 1983 (day 588), and the operating temperature was increased from 14 to 18°C (Fig. 3.1, day 588). Figure 3.2 shows that the feed flow rate was decreased from 133 L/min to 70 L/min. This was done in order to help further raise the influent

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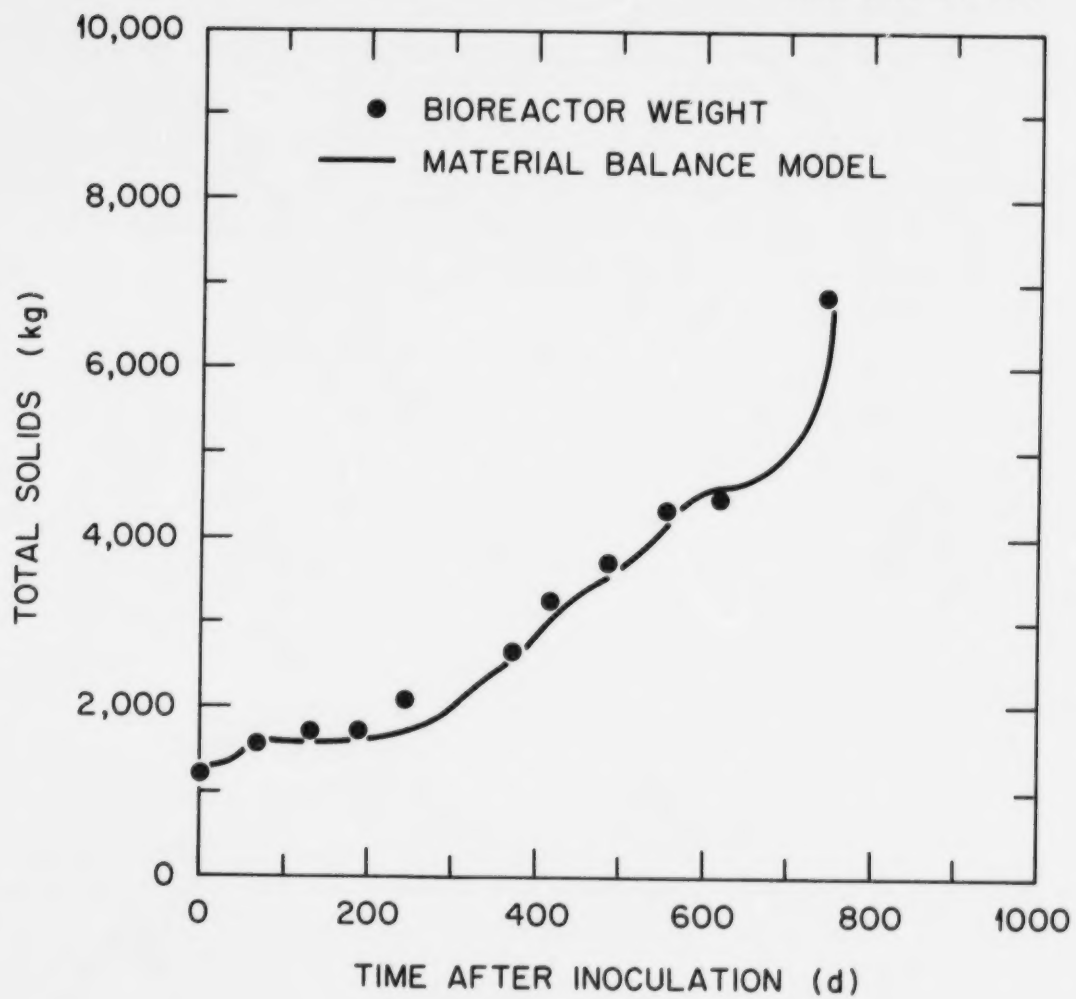


Fig. 3.18. Accumulation of solids in the bioreactor.

temperature from ~ 16 to 20°C when the preheater was in use. The flow rate was gradually increased to approximately 100 L/min by the end of June. The simulated warm-up period lasted from March 16, 1983 to June 30, 1983 (days 588 to 695).

3.3.1 Influent and Effluent Characteristics

The monthly average temperatures for March, April, May, and June were 16 ± 2 , 20 ± 2 , 24 ± 2 , and $23 \pm 4^{\circ}\text{C}$, respectively. Monthly average influent and effluent pH values were 7.0 ± 0.1 and 6.6 ± 0.1 for March, 6.8 ± 0.1 and 6.7 ± 0.5 for April, 7.3 ± 0.1 and 7.1 ± 0.1 for May, and 7.0 ± 0.2 and 6.8 ± 0.2 for June. The lower effluent pH was probably due to the formation of organic acids in the reactor; however, the natural alkalinity of the wastewater buffered the effect of organic acid formation on reactor pH.

Daily influent and effluent TSS ranged from 30 to 100 mg/L and 5 to 20 mg/L, respectively (Fig. 3.4). Monthly influent and effluent TSS concentrations ranged from 51 ± 9 to 94 ± 42 mg/L and 11 ± 3 to 17 ± 8 mg/L, respectively. Percent removals based on monthly average influent and effluent values ranged from 75 to 84. Monthly average influent and effluent VSS values ranged from 44 ± 9 to 78 ± 36 and 11 ± 3 to 14 ± 5 , respectively. Volatile suspended solids reductions based on monthly average influent and effluent data ranged from 72 to 83%.

Daily influent and effluent COD varied from 90 to 230 mg/L and 50 to 115 mg/L, respectively (Fig. 3.6). Monthly average influent COD values ranged from 134 ± 35 to 300 ± 92 mg/L and effluent COD values from 81 ± 26 to 93 ± 30 mg/L. Percent COD removal varied from 37 to 55. Soluble COD daily influent and effluent concentration ranged from 30 to 80 mg/L and 20 to 90 mg/L (Fig. 3.7). Influent and effluent monthly averages ranged from 54 ± 12 to 62 ± 21 mg/L and 53 ± 18 to 66 ± 17 mg/L, respectively. In many cases during this period, the soluble COD in the effluent was greater than the influent soluble COD concentration. This was due to an increase in the rate of hydrolysis or solubilization of accumulated organic solid materials (VSS) that were not solubilized during the cold-weather period.

Influent and effluent BOD randomly varied from 50 to 130 mg/L and 15 to 50 mg/L, respectively (Fig. 3.8). The monthly BOD influent and

effluent values ranged from 73 ± 19 to 90 ± 15 mg/L and 33 ± 13 to 42 ± 9 mg/L, respectively. Average percent removals ranged from 45 to 53.

3.3.2 Gas Production

The gas production rate was stimulated by the warmer wastewater and increased from <0.025 m³/d at 14°C to ~ 1.6 m³/d (~ 0.02 m³/m³·d) during June (22°C). The methane concentration also increased from $\sim 4\%$ at 14°C to $\sim 63\%$ at 22°C. (see Figs. 3.9 and 3.10, days 588 to 695).

3.3.3 Axial Profile Sampling

Data from profile sampling at 0, 1.2, and 2.4 m (0, 4, and 8 ft) above the bottom of the packed section are given in Table 3.2. Samples were taken at operating temperatures of 18 and 23°C, and feed flow rates of 132 L/min and 70 L/min, respectively. Data during the 18°C period show soluble COD and soluble TOC reduction of 38% in the packed section with 24% soluble COD removal and 35% soluble TOC removal in the first 1.2 m of packing. The reduction in soluble COD during the 23°C period was 38%.

Table 3.2. Results from profile sampling during warm-up simulation period

Sampling level (m)	TOC (mg/L)		COD (mg/L)		TSS (mg/L)	VSS (mg/L)	Acetic acid (mg/L)
	Total	Soluble	Total	Soluble			
<u>18°C, 132 L/min</u>							
0	65	40	283	117	94	75	19
1.2	32	26	116	89	15	15	14
2.4	31	25	92	72	8	5	14
<u>23°C, 70 L/min</u>							
0			165	95	45	33	11
1.2			120	78	24	9	13
2.4			88	75	8	2	10

Acetic acid concentrations averaged 16 mg/L and 11 mg/L through the packed section during the 18 and 23°C periods, respectively.

Total suspended solids and VSS were reduced by 91 and 93% by biofiltration through the packed section during the 18°C period and 82 and 94% during the 23°C period.

3.3.4 Evaluation of ANFLOW Performance under Increasing Temperatures

3.3.4.1 Reduction in TSS

The TSS removal rate as a function of TSS loading rate is shown in Fig. 3.19. The data were subjected to a linear least squares analysis and were adequately modeled by the following simple linear equation:

$$RR_{TSS} = 0.90 LR_{TSS} - 0.01 , \quad (8)$$

or, in terms of fraction removal,

$$f_{TSS} = 0.90 - \frac{0.01}{LR_{TSS}} . \quad (9)$$

Loading rates during this period ranged from 0.05 to 0.17 kg/m³·d. Subsequently, f_{TSS} ranged from 0.70 to 0.84.

3.3.4.2 Reduction in COD

Figure 3.20 shows COD removal-vs-COD loading rate data. Chemical oxygen demand removal as a function of COD loading rate data were adequately described by the following equation:

$$RR_{COD} = 0.774 LR_{COD} - 0.10 , \quad (10)$$

or, in terms of f_{COD} ,

$$f_{COD} = 0.774 - \frac{0.10}{LR_{COD}} . \quad (11)$$

The COD loading rates for this period ranged from 0.15 to 0.39 kg/m³·d. Therefore, f_{COD} had values from 0.11 to 0.52.

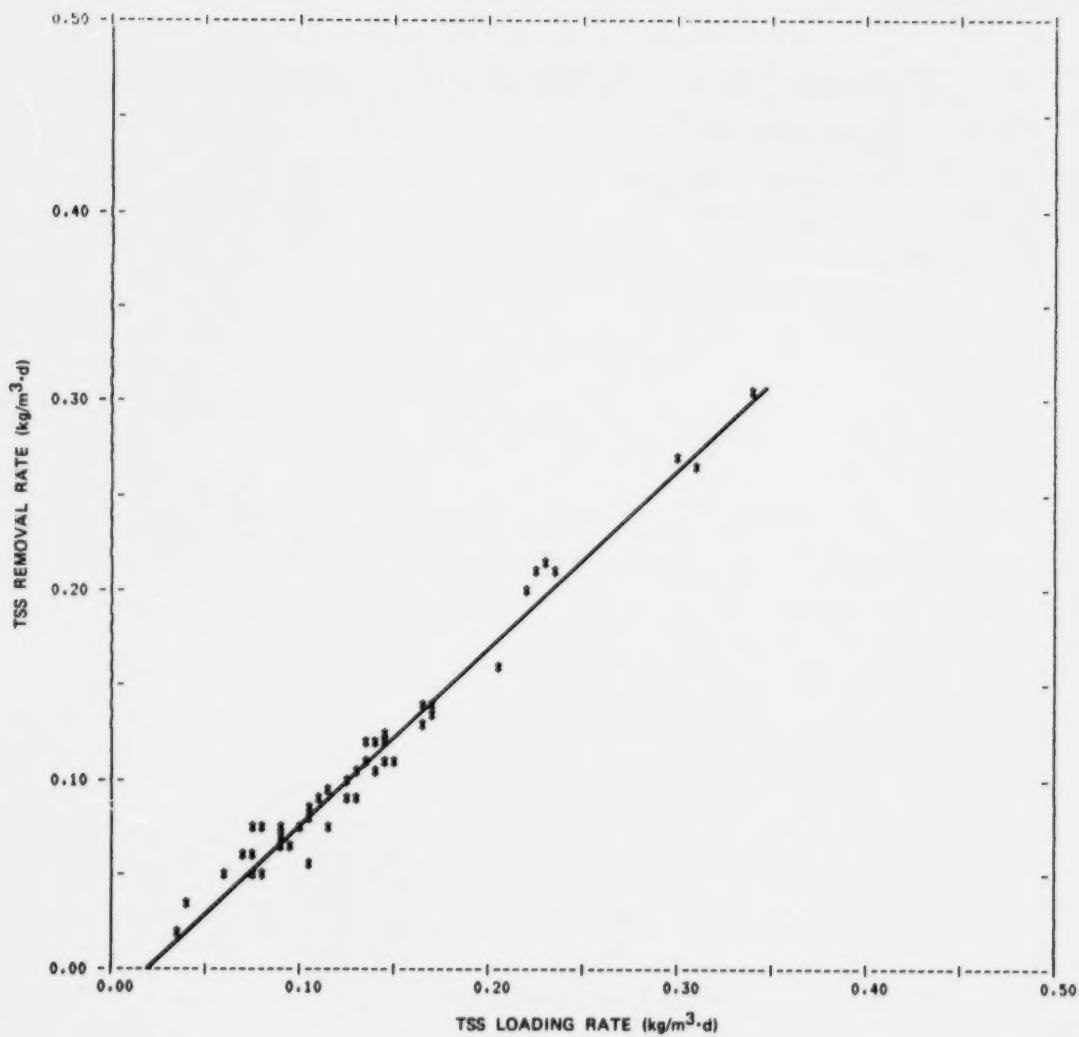


Fig. 3.19. TSS loading and removal rates during the simulated warm-up period.

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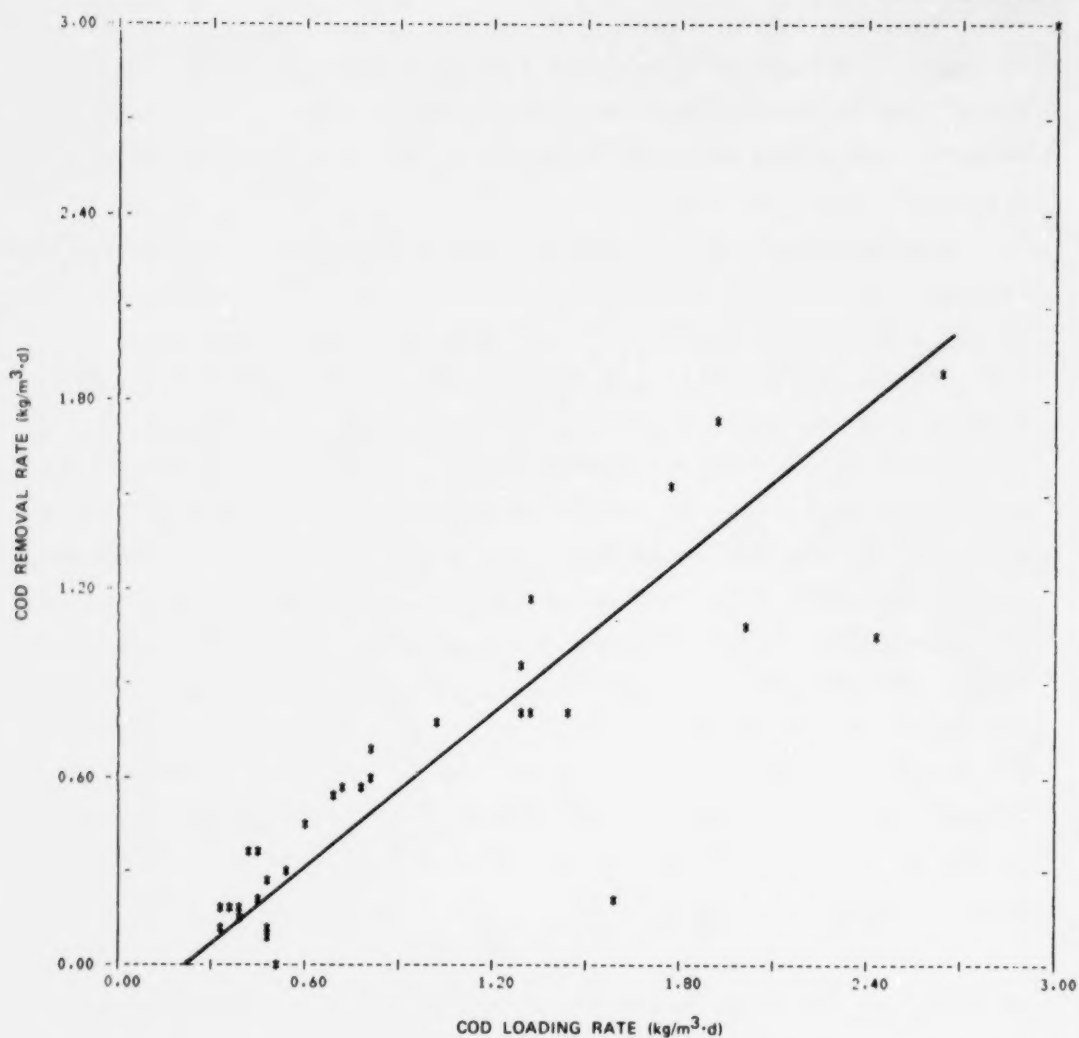


Fig. 3.20. COD loading and removal rates during the simulated warm-up period.

3.3.4.3 Anaerobic biological activity

An increase in the activity of acetogenic microorganisms was observed for the 4° increase in operating temperature from 14 to 18°C. Acetic acid concentrations in the effluent during the two periods were <1 mg/L and ~14 mg/L. The methane production also increased from ~0.5 m³/d to ~1 m³/d during the 14 and 18°C periods, respectively. When the operating temperature was increased to >20°C in April, May, and June of 1983 the methane production rate increased to ~2.5 m³/d.

Methane yield coefficients were 428 L CH₄/kg COD removed from the influent, or 646 L CH₄/kg VSS removed, in April; 319 L CH₄/kg COD removed, or 559 L CH₄/kg VSS removed, in May; and 246 L CH₄/kg COD removed, or 424 L CH₄/kg VSS removed, in June. Theoretically, 350 L CH₄/kg COD destroyed is the maximum methane yield coefficient; therefore, the high yield coefficient observed for the ANFLOW column during April was due to a substantial conversion to methane of the readily biodegradable organic solid matter that had accumulated in the column during the cold-weather operating period. This phenomenon was observed last year during March 1982 when the average temperature was increased from 14°C in January to 24°C in March. The methane yield coefficient for March 1982 was 261 L CH₄/kg COD removed from the influent. Yield coefficients for April and May 1982 decreased to 189 L CH₄/kg COD removed and 144 L CH₄/kg COD removed, respectively. This decrease in methane yield coefficients is similar to the decline seen during the simulated warm-up period in 1983.

3.3.4.4 Sludge production

From Fig. 3.18 it can be seen that during the warm-up period, the rate of sludge accumulation as estimated by the computer program decreased compared to that observed during the cold-weather period. Over the 100-d increasing temperature period, sludge was accumulated at a rate of 4 kg/d, or a total of 400 kg of dry solids. The sludge accumulation factor was, therefore, 120 kg "dry" solids/3800 m³ of wastewater treated. The sludge accumulation factor during the cold-weather period was 170 kg "dry" solids/3800 m³ of wastewater treated.

3.4 ANFLOW PERFORMANCE WITH HIGH-STRENGTH WASTEWATER

The characteristics of high-, medium-, and low-strength municipal wastewater are given in Table 3.3.²⁴ In the present study, COD and TSS concentrations were used to determine the strength of wastewater. These parameters were used because analytical results could be obtained in less than a day and, therefore, process modifications needed to maintain proper influent characteristics could be made the next day. Typically, during this high-strength wastewater study, COD and TSS concentrations were desired to range from 500 to 1000 and 200 to 500 mg/L, respectively. The experimental program covered the period July 1 to August 31, 1983 (days 695 to 756).

3.4.1 Modifications to Facility

To introduce high-strength wastewater into the ANFLOW column, a source of highly concentrated wastewater and a method for diluting and feeding the waste to the ANFLOW column were needed. The decision was made to pump sludge (~5% solids) from the underflow of the Loves Creek primary clarifier to the header of the same clarifier. There were three reasons for using sludge from the Loves Creek primary clarifier:

1. The sludge was readily available,
2. Very few process modifications had to be made, and
3. It was believed that removal of soluble organics in the biofilter could be evaluated as solubilization of the organic solids occurred.

A second centrifugal pump (solids pump) was used to transport this sludge. The solids were diluted by the wastewater entering the header and were then fed into the ANFLOW bioreactor using the normal ANFLOW intake line from this header. The solids pump was started in mid-June 1983; however, stringy types of material frequently wrapped around the impeller of the solids pump (and occasionally the feed pump) and plugged the pumps. A rough filter, which was cleaned daily, was installed upstream of the sludge pump to minimize this problem.

3.4.2 Feed Flow Rate

The average flow rate during the high-strength study was 100 L/min, which corresponds to a hydraulic loading rate of $7.7 \text{ m}^3/\text{m}^2 \cdot \text{d}$ and a theoretical residence time of 12.5 h (Fig. 3.2).

Table 3.3. Typical composition of domestic sewage
(All values except settleable solids are expressed in mg/L)

Constituent	Concentration		
	Strong	Medium	Weak
Solids, total	1000	700	350
Dissolved, total	850	500	250
Fixed	525	300	145
Volatile	325	200	105
Suspended, total	350	200	100
Fixed	75	50	30
Volatile	275	150	70
Settleable solids, mL/L	20	10	5
Biochemical oxygen demand, 5-d, 20°C (BOD ₅ -20°)	300	200	100
Total organic carbon (TOC)	300	200	100
Chemical oxygen demand (COD)	1000	500	250
Nitrogen, (total as N)	85	40	20
Organic	35	15	8
Free ammonia	50	25	12
Nitrites	0	0	0
Nitrates	0	0	0
Phosphorus (total as P)	20	10	6
Organic	5	3	2
Inorganic	15	7	4
Chlorides	100	50	30
Alkalinity (as CaCO ₃)	200	100	50
Grease	150	100	50

Source: Metclaf and Eddy, Inc., Wastewater Engineering: Collection, Treatment and Disposal, McGraw-Hill, New York, 1972.

3.4.3 Influent and Effluent Characteristics

The influent and effluent pH values (Fig. 3.3) ranged from 6.4 to 7.5 and 6.6 to 7.4, respectively. As with the cold-weather operation, the pH values were within the normal operating range for anaerobic bioreactors. The column was operated at an average temperature of 22°C, which is ~10°C below the optimal temperature for mesophillic anaerobic bioactivity.

Influent and effluent TSS varied from 100 to 600 mg/L and 50 to 140 mg/L, respectively (Fig. 3.4). The VSS concentration randomly varied from 50 to 500 mg/L for the influent and 17 to 80 mg/L for the effluent (Fig. 3.5).

Levels of COD randomly varied from 150 to 1000⁺ mg/L in the influent and 60 to 700 mg/L in the effluent (Fig. 3.6). The soluble COD concentration varied from 50 to 150 mg/L in the influent and 20 to 150 mg/L in the effluent (Fig. 3.7). The influent COD consisted of ~15% soluble COD. The BOD concentrations ranged from 150 to 250 mg/L in the influent and 40 to 100 mg/L in the effluent (Fig. 3.8).

Several samples collected during this period were analyzed for acetic acid and sulfide. Influent and effluent samples taken on August 10, 1983 contained 0 and 15 mg/L acetic acid, respectively. Influent H₂S concentrations were 1 mg/L (two samples), and effluent H₂S concentrations were 10 mg/L (one sample).

3.4.4 Axial Profile Sampling

Profile sampling was done on four separate occasions during the high-strength wastewater study. These data, presented in Table 3.4, show random variation in the TSS and VSS concentrations and, therefore, suggest an irregular solids distribution throughout the packed bed. Total COD showed similar variations in the packed section. Soluble organic concentrations (soluble COD) also varied with the VSS and TSS concentrations. Soluble COD concentration as high as 1850 mg/L was observed at the bottom of the packing when the VSS concentration was 29,800 mg/L.

Volatile acid concentrations were observed as high as 120 mg/L acetic acid, 50 mg/L propionic acid, 5 mg/L isobutyric acid, and 15 mg/L n-butyric acid. The variation of soluble COD with VSS in the packed section, as observed on July 21, 1983, and the variation of acetic acid and propionic acid with VSS in the packed section, as observed on August 10, 1983,

Table 3.4. Results from profile sampling

(100 L/min, 22°C)

Sampling level (m)	COD (mg/L)		TSS (mg/L)	VSS (mg/L)	Volatile acids			
	total	soluble			acetic (mg/L)	propionic (mg/L)	i-butyrlic (mg/L)	n-butyrlic (mg/L)
<u>7/14/83</u>								
0	760	97	398	260				
1.2	1,930	97	880	604				
2.4	174	71	76	56				
<u>7/21/83</u>								
0	66,000	1,850	59,900	29,800				
1.2	12,650	550	7,300	4,800				
2.4	245	47	174	116				
<u>8/5/83</u>								
0			1,936	1,438	120	50	5	15
1.2			2,690	1,950	10			
2.4			2,026	1,454	20			
<u>8/10/83</u>								
0	3,350		1,400	1,300	25	35		
1.2	1,550		800	800	15	10		
2.4	15,300		9,500	7,100	50	25		

suggest that hydrolysis of organic solids and the formation of organic acids were occurring near the top of the packed section. Since less time was allowed for methanogenesis, this probably caused the higher effluent soluble COD that was observed during the high-strength wastewater period.

3.4.5 Gas Production

Off-gas production rates during this period ranged from 2 to $>10 \text{ m}^3/\text{d}$ (0.027 to $0.13 \text{ m}^3/\text{m}^3 \cdot \text{d}$). The methane concentration in the off-gas increased from 60 to 80%. Figures 3.9 and 3.10 show the off-gas production rate and percent methane in the off-gas. Approximately $3 \text{ m}^3/\text{d}$ of methane was dissolved and removed via the liquid effluent.

3.4.6 Evaluation of ANFLOW Performance with High-Strength Wastewater

3.4.6.1 Reduction in TSS

The response of ANFLOW to TSS loading rates during the high-strength wastewater study is shown in Fig. 3.21. Approximately 85% of the data fall between lines indicating 50 and 100% removals; 10% of the data showed 25 to 50% removals; and 5% of the data indicated $<25\%$ removals. Thus, for TSS loading rates ranging from 0.19 to $1.2 \text{ kg}/\text{m}^3 \cdot \text{d}$, the ANFLOW column was, for the most part, capable of removing $>50\%$ of the influent TSS. Percent removals based on monthly average influent and effluent TSS values ranged from 71 to 85%.

3.4.6.2 Reduction in COD

The COD removal rate as a function of COD loading rate (Fig. 3.22) is represented by the following linear least squares equation:

$$\text{RR}_{\text{COD}} = 0.81 \text{ LR}_{\text{COD}} - 0.16 . \quad (12)$$

The corresponding equation for fractional removal is:

$$f_{\text{COD}} = 0.81 - \frac{0.16}{\text{LR}_{\text{COD}}} . \quad (13)$$

The daily COD loading rates ranged from 0.29 to $>1.92 \text{ kg}/\text{m}^3 \cdot \text{d}$, and COD fractional removals ranged from 0.26 to >0.76 . Monthly average COD reductions, based on monthly average influent and effluent COD values, ranged from 68 to 73%. There was essentially no soluble COD removal during this period.

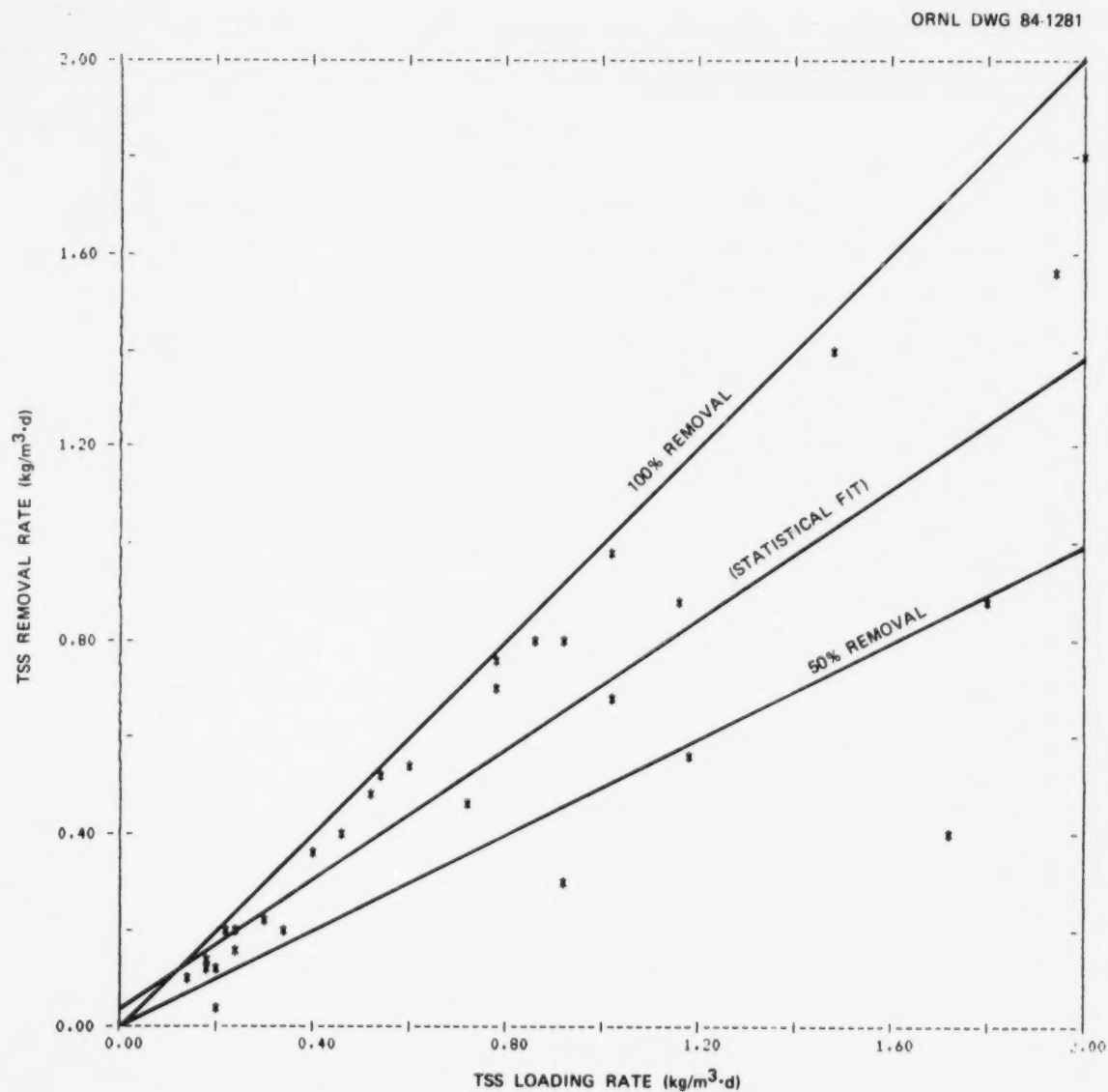


Fig. 3.21. TSS loading and removal rates during the high-strength wastewater period.

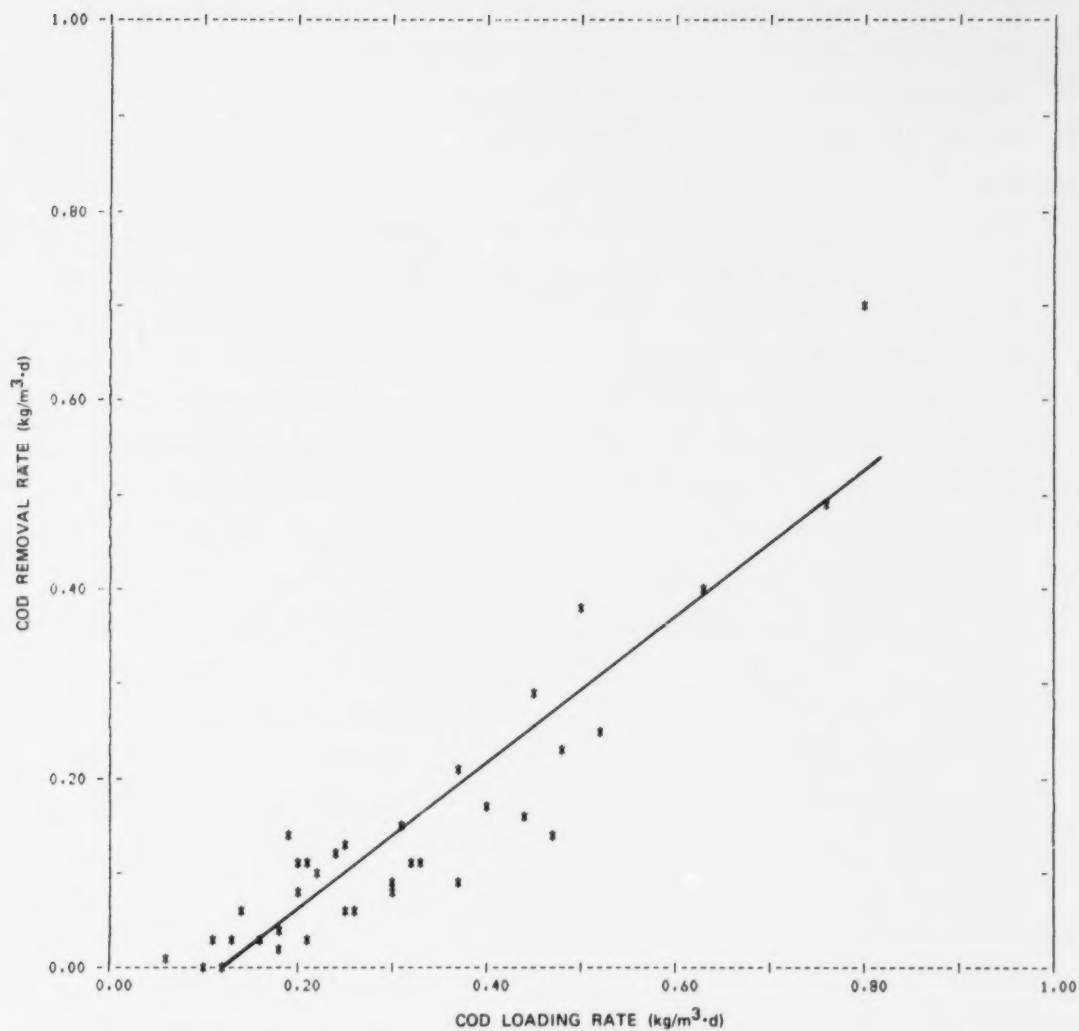


Fig. 3.22. COD loading and removal rates during the high-strength wastewater period.

3.4.6.3 Anaerobic biological activity

The methane production rate reached values $>10 \text{ m}^3/\text{d}$ ($0.13 \text{ m}^3/\text{m}^3 \cdot \text{d}$) during the high-strength study. Methane yield coefficients of 72 to 152 L CH_4/kg COD removed and 132 to 314 L CH_4/kg VSS removed were, however, lower than those observed during the simulated warm-up period (276 to 428 L CH_4/kg COD and 424 to 646 L CH_4/kg VSS). This indicated that the rate of conversion of solid organic matter (VSS) to methane was significantly less than the VSS loading rate. The presence of volatile organic acids in the packed section and the liquid effluent also suggested that the rate-limiting step was the conversion from volatile acids to methane gas. It should be noted that Figs. 3.9 and 3.10 show an increase in off-gas production and methane concentration throughout the high-strength study. Thus, it was postulated that the microbial population was acclimating to the higher substrate concentration, and the methane yield would probably approach a steady-state value of $>150 \text{ L CH}_4/\text{kg}$ COD removed.

3.4.6.4 Sludge production

An estimated 4850 kg of dry solids had accumulated in the bioreactor prior to the high-strength wastewater study (Fig. 3.18), and $\sim 1800 \text{ kg}$ was accumulated during this period. For the high-strength wastewater study, the solids accumulation rate was 21 kg/d , and the accumulation factor was $\sim 575 \text{ kg solids}/3800 \text{ m}^3$ of wastewater treated. The computer program and bioreactor weight estimates were in good agreement, as shown in Fig. 3.18.

Samples of sludge removed from the bottom of the column indicated that the dry solids contained $\sim 60\%$ volatile solids. This was slightly lower than the computer program estimate of 68% ; however, the estimates were in reasonably good agreement.

3.5 COMPARATIVE ANALYSES OF ANFLOW PERFORMANCE UNDER VARYING CONDITIONS

Table 3.5 summarizes the performance of the $190\text{-m}^3/\text{d}$ ANFLOW pilot plant. These data were evaluated to detect trends in the response of the ANFLOW column to temperature and loading rate changes.

3.5.1 Variation in Effluent pH and Effluent Volatile Acid Values

The effluent pH values were affected very little by variations in temperature from 12 to 26°C . This suggests that the natural buffering capacity of wastewater was sufficient to compensate for pH changes associated

Table 3.5. Operation and performance summary
for the 190-m³/d ANFLOW pilot plant^a

Operating or performance parameter	Raw wastewater		Raw wastewater plus primary clarifier underflow
	Cold weather	Temperature control to >20°C	Temperature control to >20°C
Temperature of feed, °C	12-18	20-25	22
Period of operation, d	137	213	61
Hydraulic loading rate, m ³ /m ² ·d	10.0	7.3	7.3
TSS loading rate, kg/m ³ ·d	0.15	0.12	0.73
BOD loading rate, kg/m ³ ·d	0.13	0.23 ^b (0.14) ^c	0.40
COD loading rate, kg/m ³ ·d	0.35	0.30	1.2
TSS removal efficiency, %	80	80	78
BOD removal efficiency, %	63	69 ^b (50) ^c	70
COD removal efficiency, %	50	57 ^b (45) ^c	71
Methane yield coefficient, L CH ₄ /kg COD removed	50	160	110
Volumetric CH ₄ production rate, L CH ₄ /m ³ reactor·d	9	24	94
Concentration of CH ₄ in off-gas, %	3-9	63-76	60-80
Sludge production rate, kg dry solids/3800 m ³ of wastewater treated	170	200 ^b (120) ^c	575

^aAll average values were derived from monthly averages.

^bValues observed during the start-up period.

^cValues observed during the increasing temperature period.

with volatile acid production. During the cold-weather period, acetic and other volatile acids were not detected in the packed section or the effluent, and the pH values averaged ~6.6.

When temperatures were increased to 18°C during the simulated warm-up period, the acetic acid concentration in the packed section and the liquid effluent increased to ~15 mg/L, and the effluent pH gradually decreased to 6.3. This level of acetic acid was also observed in the effluent during the high-strength study. Effluent pH ranged from 6.3 to 7.8 and averaged 7.0 during the high-strength study. Overall, the pH was maintained within the acceptable limits, 6 to 8, by the natural alkalinity of the wastewater.

3.5.2 Removal of TSS

Effluent TSS was consistently <30 mg/L for temperatures varying from 12 to 25°C and TSS loading rates averaging ~0.13 kg/m³·d. During the high-strength wastewater period, when TSS loading rates ranged from 0.19 to 1.2 kg/m³·d, effluent TSS increased to a range of ~50 to 140 mg/L. The TSS and VSS concentrations in the influent and effluent correlated reasonably well, as would be expected. The TSS removal efficiencies decreased from 80% for a TSS loading rate of ~0.13 kg/m³·d to ~60% for TSS loading rates >0.73 kg/m³·d; however, the large accumulation of sludge in the reactor during the high-strength wastewater study probably contributed to the lower removal efficiency for TSS during this period.

3.5.3 Removal of COD and BOD

Average total COD and total BOD removal efficiencies were minimal (45 and 50%) under increasing operating temperatures and maximal (71 and 70%) during the high-strength wastewater study. Unlike effluent TSS, effluent BOD levels occasionally exceeded 30 mg/L during the raw water operating periods. This was especially prevalent during the increasing temperature period. It was observed that during this period, easily biodegradable organic solid matter that accumulated in the bottom of the bioreactor over the cold-weather period was converted to soluble organics. A subsequent increase in soluble organic load to the packed section was observed, and although a 38% reduction in soluble COD was observed through the packed section, effluent soluble COD was greater than influent values. Therefore, COD (and, likewise, BOD) removal efficiencies were lowered.

The higher COD and BOD removal efficiencies that were observed during the high-strength wastewater study can be explained by comparing the fraction of soluble COD in the influent total COD during the low-strength wastewater periods (37%) with the fraction of soluble COD during the high-strength wastewater study (15%). Since during the high-strength wastewater study 85% of the total influent COD was insoluble, COD and, likewise, BOD removal efficiencies of 70 and 71% approached the TSS removal efficiency of 78%. The higher fraction of soluble COD during the low-strength wastewater period and the low soluble COD removal efficiency resulted in total COD and total BOD removal efficiencies that were significantly lower than the TSS removal efficiency during raw wastewater operating periods.

In general, no good correlation occurred between BOD and COD concentrations in the influent and effluent, which suggests considerable variation in the composition of the wastewater. Insoluble COD and VSS were only weakly correlated.

3.5.4 Gas Production

The decreasing off-gas production from $1 \text{ m}^3/\text{d}$ during the decreasing-temperature period to $<0.1 \text{ m}^3/\text{d}$ during the cold-weather period shows the tremendous effect that operating temperature has on methane production. For temperatures of $\sim 14^\circ\text{C}$, off-gas production was $<0.025 \text{ m}^3/\text{d}$, with practically all of the biologically generated methane being removed via the liquid effluent.

When temperatures were increased to 18°C during the period of increasing temperature, methanogenesis was only slightly increased. However, when the temperature was increased to $>20^\circ\text{C}$ the methane production increased to $\sim 1.6 \text{ m}^3/\text{d}$.

During the high-strength wastewater period, where the COD loading rates ranged from 0.29 to $>1.92 \text{ kg}/\text{m}^3\cdot\text{d}$, and the temperature was 22°C , the off-gas production rate increased from $2 \text{ m}^3/\text{d}$ to $>10 \text{ m}^3/\text{d}$, with the methane in the off-gas ranging from 60 to 80%.

3.5.5 Sludge Production

The accumulation of solids in the bioreactor for the four periods is best compared in terms of the solids accumulation factor, kg solids

accumulated per 3800 m³ (million gal) of wastewater treated. From Table 3.5, sludge accumulation factors were ~200 kg dry solids per 3800 m³ of wastewater treated for raw wastewater alone and 575 kg dry solids per 3800 m³ of wastewater treated for the raw wastewater plus primary clarifier underflow. The 120 kg/3800 m³ accumulation factor observed during the increasing temperature period was, as previously stated, due to the conversion of accumulated solids to soluble organics and methane.

The high sludge accumulation factor for the high-strength wastewater period suggests that, although the off-gas production rate increased tremendously during this period, the insoluble organic loading rate was significantly greater than the subsequent conversion to soluble organics and ultimately to methane gas.

4. SPECIAL TESTS

4.1 SOLUBLE COD TESTS

In early September 1983, addition of sludge from the primary clarifier was discontinued after ~3 months of operation, and a higher-strength soluble COD test was initiated. An aqueous concentrate of dextrose and cane sugar was used to supplement the raw wastewater feed for a period of 4 d. Results from this test are summarized in Table 4.1. Data from axial profile samples before and during the soluble COD tests are given in Table 4.2. The reduction in soluble COD was reflected in an increase in off-gas production of 3 to 5 m³/d (compare the off-gas production rate during days 1, 3, and 4 with the production rate during day 2 when sugar was unintentionally omitted from the bioreactor). The 64% removal efficiency observed on the fifth day of this test was probably artificially high; the main wastewater feed pump was down for ~19 h, and only the aqueous sugar concentrate was fed to the bioreactor.

The axial profile samples showed a slight increase in both acetic acid and propionic acid concentrations through the packed section. As with the data collected during the high-strength wastewater study, there appears to be some indication that, due to random distribution of solids in the packed section, volatile acids are produced throughout the packed section.

Table 4.1. ANFLOW response to high soluble COD test
(Feed flowrate = 100 L/min, temperature = 23°C)

Day	Soluble COD (mg/L)		Removal efficiency (%)	Off-gas production rate (m ³ /d)	Methane in off-gas (%)	Comments
	influent	effluent				
1	340	162	52	8.58	78	Good data
2	—	—	—	5.58	80	Because of plugged check valve, very little sugar was pumped to bioreactor
3	—	—	—	10.4	76	Good data
4	411	282	31	10.1	74	Good data
5	395	142	64	—	—	Feed pump was down for ~19 h; therefore, only concentrated sugar solu- tion was pumped into bioreactor

Table 4.2. Results from axial profile samples taken before and during
high soluble COD test

Sampling level (m above bottom of packing)	Acetic acid (mg/L)	Propionic acid (mg/L)
Before test		
0	31	3
1.2	21	7
2.4	21	1
During test		
0	36	18
1.2	28	11
2.4	46	16

4.2 RESIDENCE TIME DISTRIBUTION TESTS

Determining the flow characteristics in a reactor system is essential for developing adequate kinetic models. Residence time distribution (RTD) tests were conducted on the ANFLOW column before inoculation and after >5000 kg (dry basis) of solids had accumulated in the bioreactor. An inert fluorescein dye was injected into the feed pipe directly before the bottom cone. During the RTD tests before inoculation, the dye passed through the bottom cone, packed section, liquid overflow, and the effluent holding tank where samples were taken, and the dye concentration was determined via a photodensitometer.

The RTD tests that were performed at the end of the project were not allowed to pass through the effluent holding tank, and the dye concentration was determined with a fluorometer.

Experimental results from typical tests at the beginning and the end of the project are represented in Figs. 4.1 and 4.2 in terms of conventional age distribution functions, which vary with the normalized residence time.²⁵ The age distribution function, E , is defined such that the fraction of the exit stream with residence time in the reactor between time t and $t + dt$ is given by $E dt$. The dimensionless time, θ , is defined as $t/\bar{t}$, where $\bar{t}$ is the mean residence time given by the total reactor volume divided by the volumetric flow rate.

A one-parameter model widely used to represent nonideal flow is the tanks-in-series model.²⁵ From the formalism of this model, it is relatively straightforward to estimate the number of ideal stirred tanks that approximately reproduce the experimental RTD. This may be done by visual comparison of the experimental data with parametric plots (e.g., ref. 25, p. 292), or by more rigorous mathematical procedures.

The response curves that were observed during the initial tests (before inoculation) indicated that the flow patterns in the ANFLOW bioreactor were best described by a series of three unequal-volume tanks with volume ratios of 1:3:6.²⁶ The mean residence time, $\bar{t}$, calculated from these initial data showed anomalous behavior in that $\bar{t}$ at 100 L/min was less than $\bar{t}$ for 210 L/min.

Response curves that were obtained from the RTD tests conducted at the end of the pilot plant study showed a substantial reduction in the

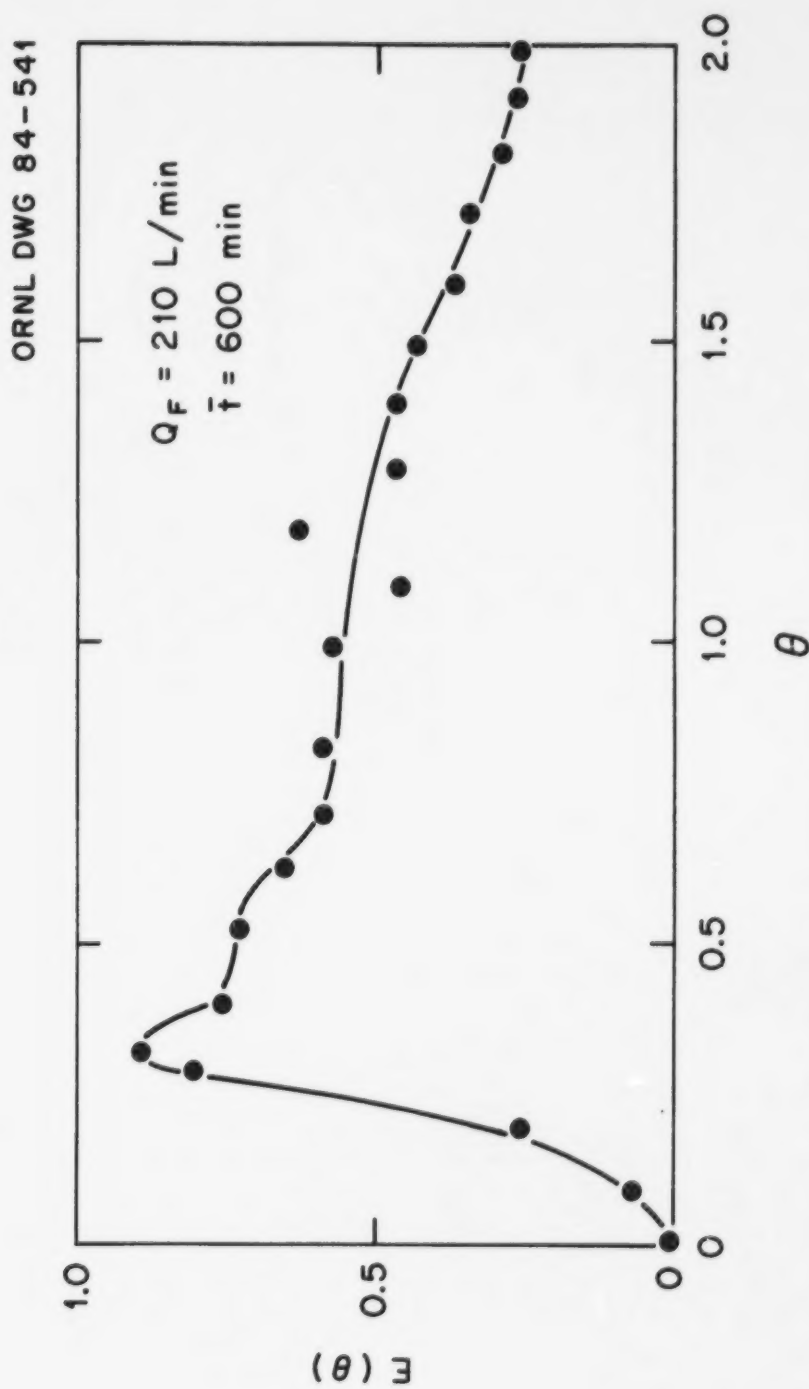


Fig. 4.1. Normalized response curve for the residence-time-distribution (RTD) test before inoculation.

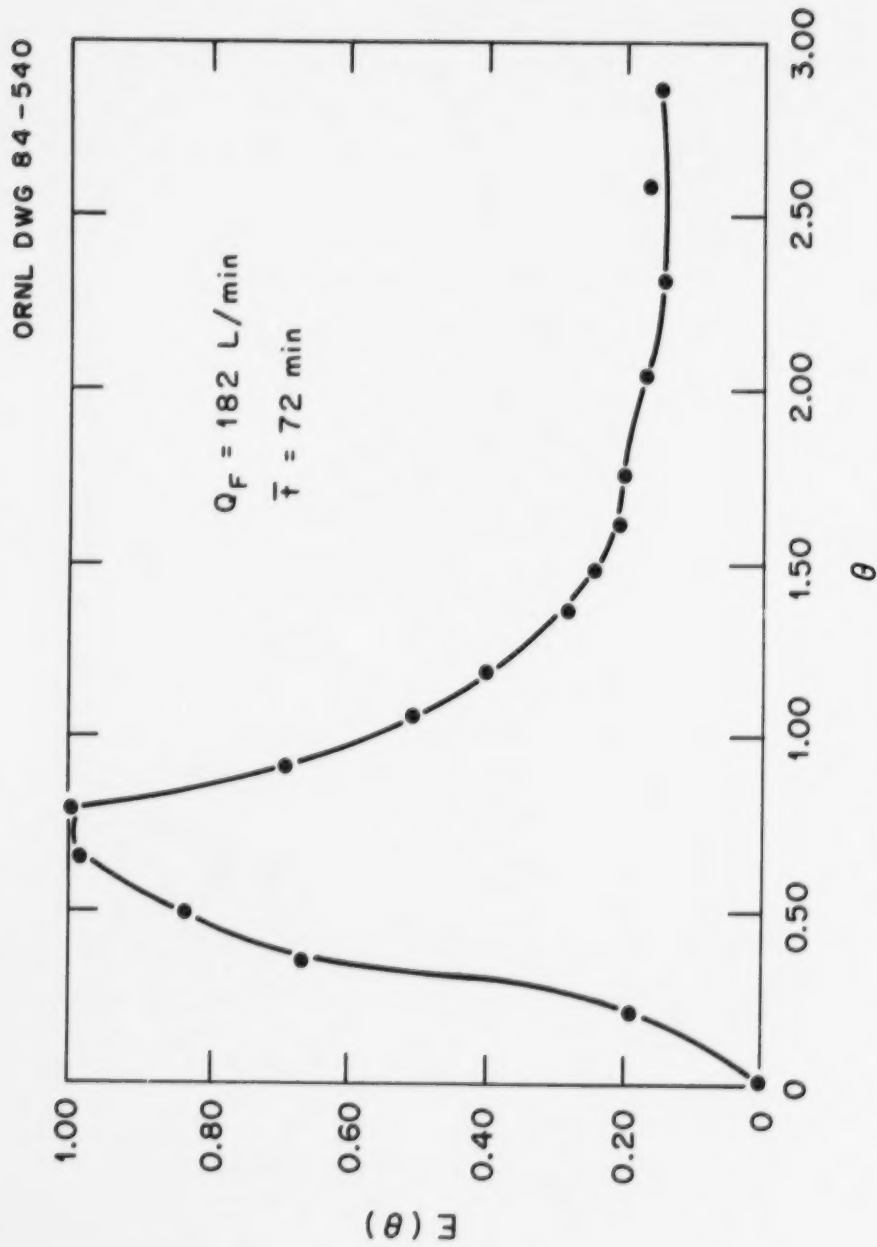


Fig. 4.2. Normalized response curve for the RTD test after the completion of the high-strength wastewater period.

mean residence time. Two tests were conducted at feed flow rates of 170 and 182 L/min. During the test at 170 L/min, the feed pump plugged right after the dye was injected. The system was shut down for ~5 min to unplug the pump. The measured mean residence time was ~80 min with ~70% recovery of the dye. Response data for the tracer test at 182 L/min indicated a mean residence time of ~72 min with ~80% recovery of the tracer dye. Theoretical mean residence times for 170 L/min and 182 L/min were 441 and 412 min, respectively. Thus, approximately one-sixth of the total reactor volume was used, and the other five-sixths of the bioreactor was (apparently) occupied by solids and/or stagnant zones (dead volume).

The flow patterns in the reactor could be described by two equal-volume, continuous-stirred-tank reactors in series.

4.3 EVALUATION OF METAL TEST COUPONS

To evaluate the response of seven types of paint to the highly corrosive atmosphere in the ANFLOW column, 316 stainless steel metal test coupons were evenly coated and placed in the top of the ANFLOW column. The coupons were located such that they would be exposed to both the liquid and gas phases. Figure 4.3 shows the metal test coupons resting on the top metal grating in the ANFLOW column.

The type of paint used and the observations made after the coupons were subjected to the corrosive atmosphere in ANFLOW for ~800 d are given in Table 4.3. The Amercoat 395/395 paint sample showed no signs of paint peeling or any indication of reactivity with the corrosive atmosphere. The Sikagard 62-gray also showed high resistance to the corrosive atmosphere. Overall, the gas phase was more reactive to the paints than was the liquid phase.

4.4 REMOVAL OF SOLIDS

From the solids mass balance model and the bioreactor weights, it is estimated that there were ~6800 kg of solids in the ANFLOW column at the completion of the experimental program in early October 1983. Based on previous sludge analyses, a reasonable assumption for the average concentration of TSS in the settled sludge is 100,000 mg/L (10%).

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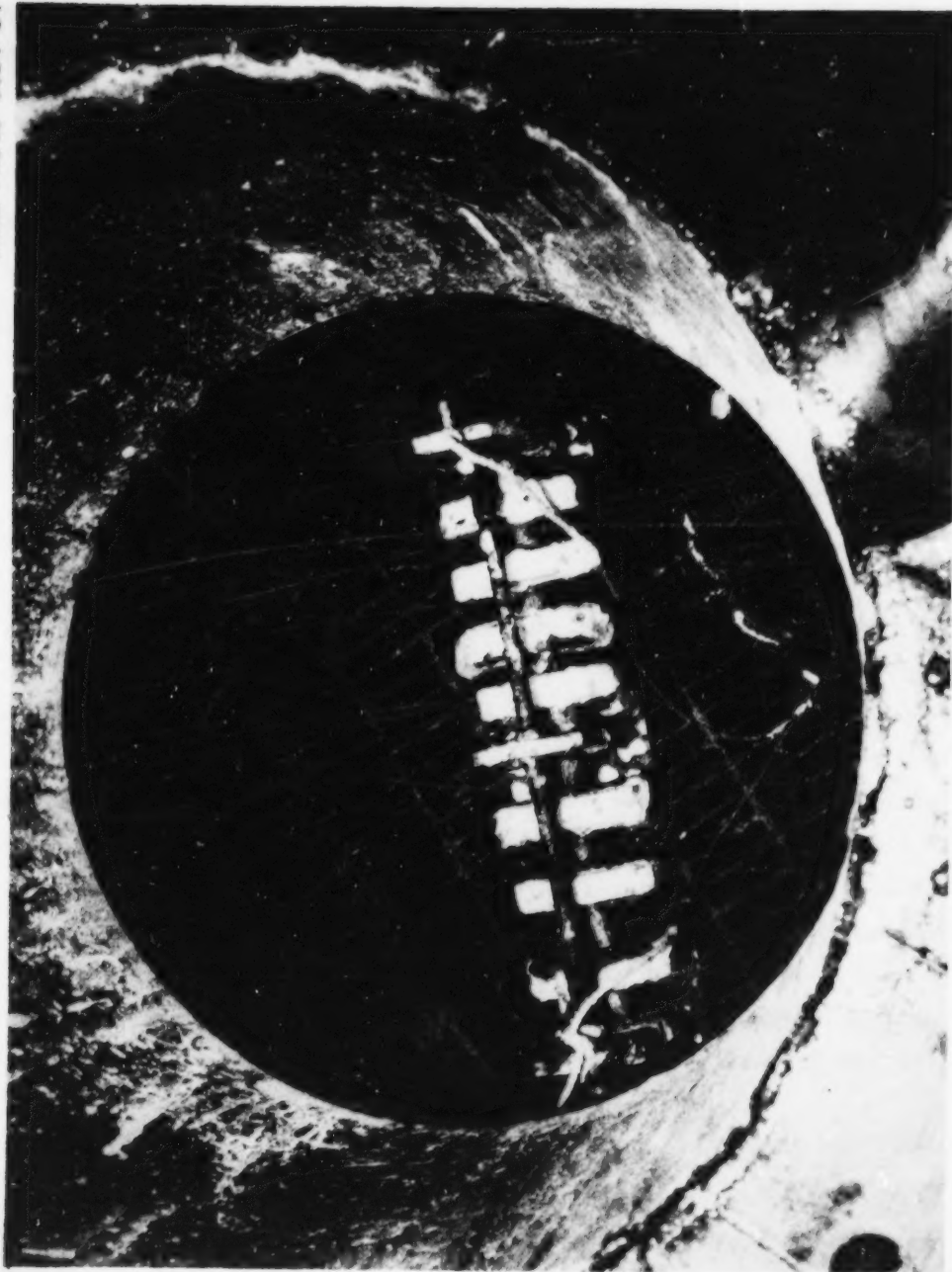


Fig. 4.3. Metal test coupons at the gas-liquid interface in the ANFLOW bioreactor.

Table 4.3. Results from metal coupon test^a

Label	Type of paint	Exposed to liquid phase			Exposed to gas phase	
		Original color of paint	Color of paint	Paint peeling or blistering (%)	Color of paint	Paint peeling or blistering (%)
A	Sikagard-62 gray	Black	Black	0	Black	<1
B	Amercoat 395/395	Black	Black	0	Black	0
C	Amercoat 90/90	White	White	~60	—	100
D	Amercoat 33/33/33	White	White	~5	White	~10
E	Sikagard-624	White	Gray	~10	White	~95
F	Carboline #300/302/302 and Phenoline #18931 (8 mL each)	White	White	~50	White	~50
G	Carboline 14/14 and Carbomastic 18931 (8 mL each)	Gray	Gray	~10	White	~95

^aObservations after samples were mildly rinsed with tap water. Total exposure time was ~800 d. The liquid phase covered ~75% of each coupon, and the gas phase covered ~25% of each coupon.

Therefore, the sludge volume in the column would be 68,000 L or 68 m³, which corresponds to a sludge level of ~2.5 m (~8.3 ft) above the bottom of the packing. Although the observed TSS concentration in the packing is much less than 100,000 mg/L (see Table 3.4), the TSS concentration in the bottom cone may well be >100,000 mg/L. Note that this approximate calculation does predict a significant concentration of TSS in the packing, which is observed in the data in Table 3.4. This accumulation of solids in the packing probably contributed to the high effluent BOD and TSS concentrations during the high-strength wastewater operation.

During the latter portion of September 1983, several experiments were performed to assess procedures for discharging solids from the bioreactor. First, the feed flow was stopped, and the valve at the bottom of the cone was opened. Approximately 300 kg of dry solids discharged, corresponding to ~4300 L of wet sludge. The system was then operated for several days at a very high liquid flow rate of 350 to 380 L/min (130,000 to 140,000 gpd) to determine if solids could be flushed from the column in the upflow mode. The TSS in the effluent was ~100 mg/L, or equal to the influent TSS. In other words, upflow was an ineffective procedure to remove solids. This test is not believed to be an indicator of performance of the bioreactor at high flow rates to treat wastewater since the column is believed to have been overloaded with solids inventory when this experiment was performed.

Operation was converted to downflow for several days at 130 L/min to flush solids from the bioreactor. This approach also proved ineffective for solids removal.

The bioreactor was then drained of all liquid through the 10-cm (4-in.) line at the bottom of the cone. Samples were taken periodically for later analysis to determine the quantity of solids. A substantial quantity of solids appeared to be removed. When the bioreactor was subsequently refilled with water to resume operation, the weight of the system had been reduced by 200 kg, as indicated by the weigh cells. When buoyancy effects are considered, this weight loss of 220 kg translates to ~900 kg of dry solids that were discharged.

After the bioreactor was drained, the quantity of wastewater required to refill it was measured. This amount was 90% of the quantity required to fill it 2 years previously when operation began, although only <20% of the solids were discharged. It appears that water will drain from the sludge, while the solids are retained in the packing. These observations, combined with the RTD studies showing a significant decrease in the mean residence time, suggest that significant channeling of the liquid flow occurred when the column was heavily loaded with solids.

5. DECOMMISSIONING OF THE PILOT PLANT

5.1 REMOVAL AND INSPECTION OF PLASTIC PACKING

Prior to removing all of the packing material, several of the plastic rings were removed via 24-in. manholes in the top and side. Figure 5.1 shows the removal of the top manhole cover. The packing material that was removed via the top manhole is shown in Fig. 5.2. The picture shows some attachment of sludge to the packing material. This packing showed no signs of internal plugging. The packing taken from the side manhold, which is located near the bottom of the packing, had considerably more sludge loosely trapped in ~50% of the original free space of the packing.

For the removal of all the packing material, the biomass in the column was disinfected, and health hazards were minimized by adding calcium hypochlorite to the system and operating in the total recycle mode. This was continued until a residual chlorine concentration of 2.0 mg/L was maintained in the bioreactor for at least 12 h. To avoid the possibility of injecting toxic levels of residual chlorine into the Loves Creek wastewater treatment facility, sufficient sodium sulfite was added and recycled through the ANFLOW column for 1 d. The column was drained after the disinfection step, and the packing was removed and disposed in a local sanitary landfill.

Figure 5.3.a shows the contrast between the original clean packing material and the packing material removed from the ANFLOW column after 806 d of operation. The sludge occupied from <10 to ~50% of the original free space. The solids tended to accumulate more along the walls of the

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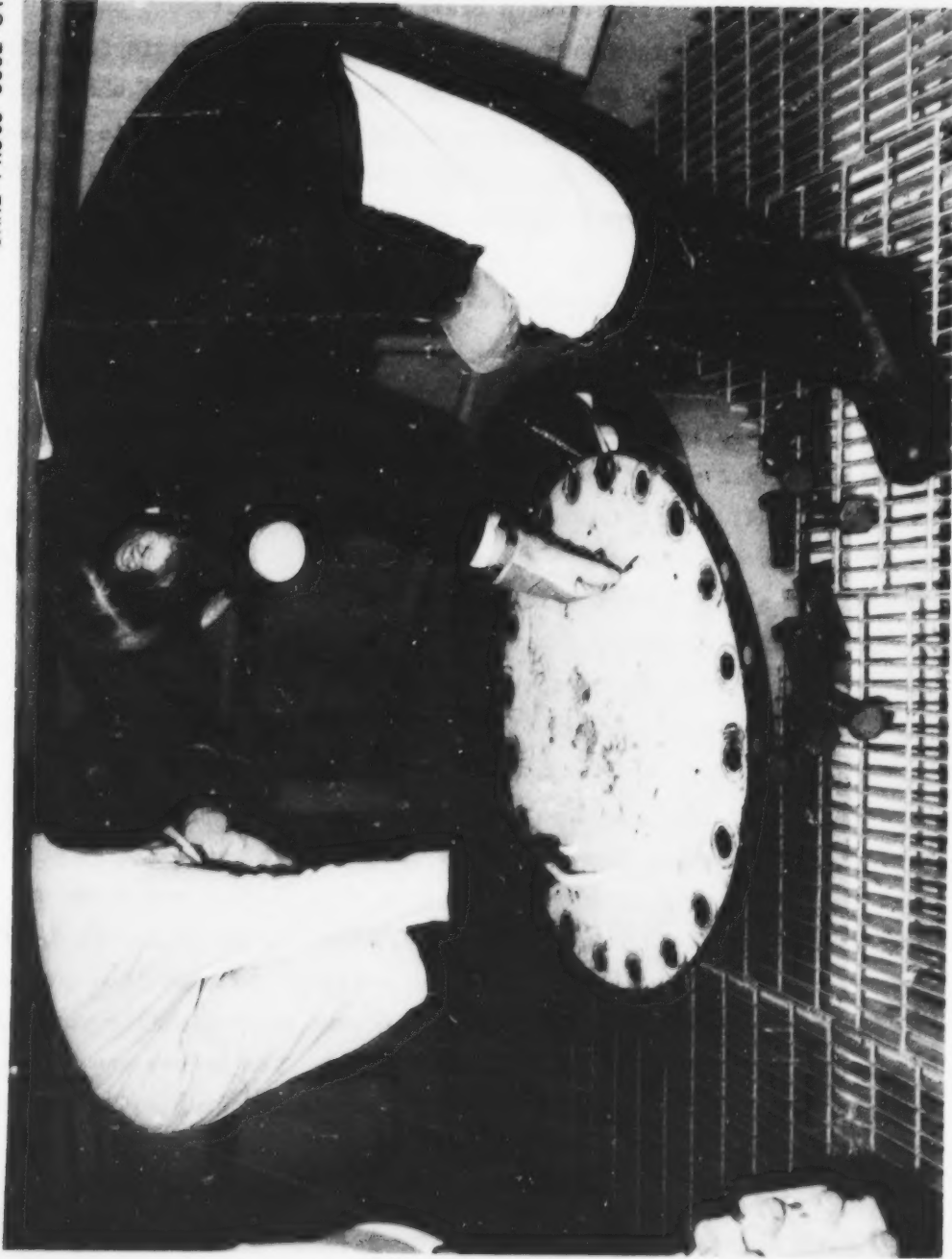


Fig. 5.1. Removal of the top manhole cover.

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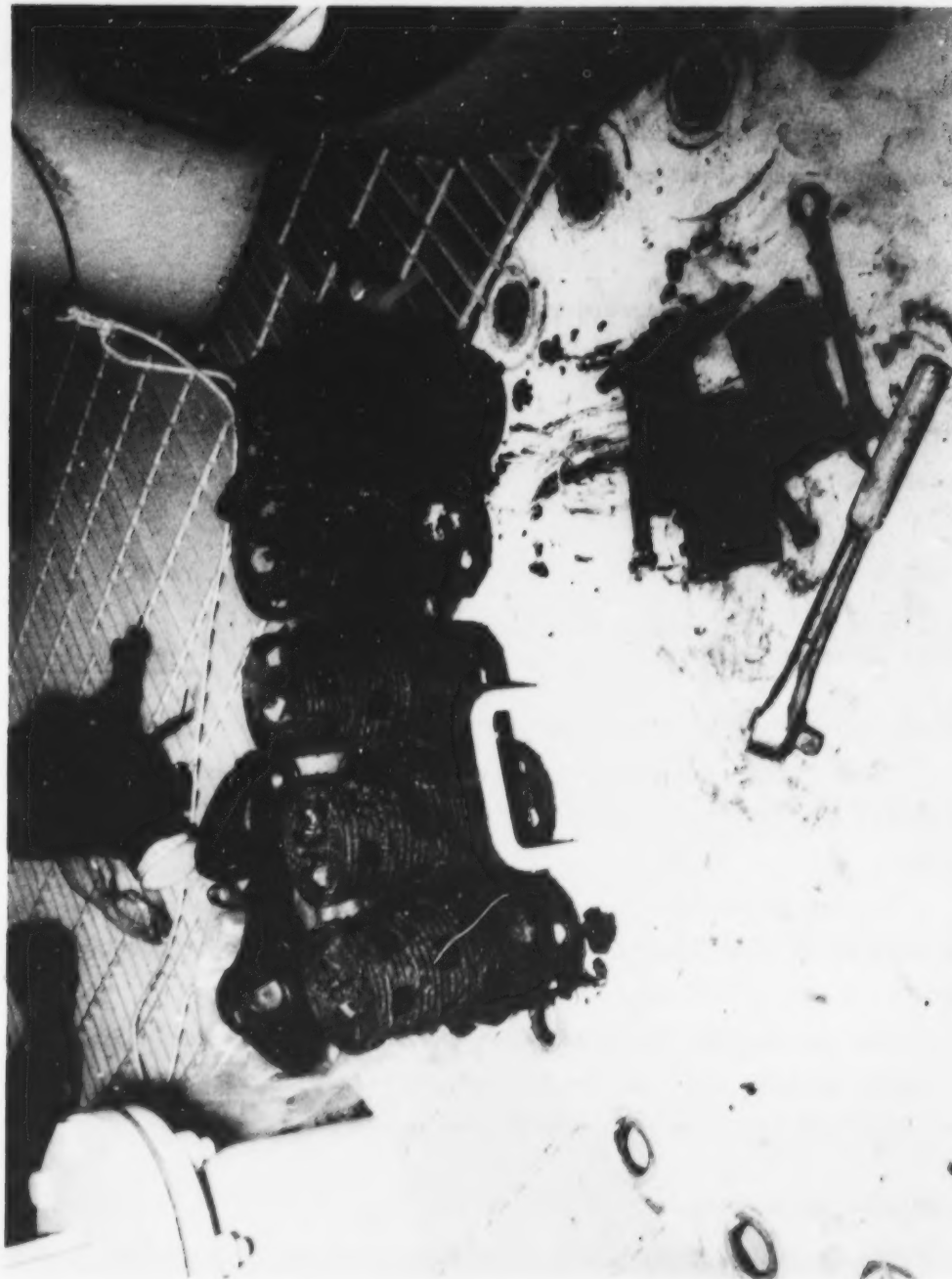


Fig. 5.2. Packing removed from the top manhole opening.

column. Overall, there were no signs of column plugging, and the sludge was easily removed by spraying the packing with water. Figure 5.3.b shows the packing after rinsing.

Based on the change in bioreactor weight before and after removal of the packing and correcting for the weight of the plastic packing, ~7500 kg of wet sludge was attached to and trapped in the plastic packing. This sludge contained 1500 kg of dry solids.

5.2 SOLIDS INVENTORY

The amount of sludge (dry basis) accumulated in the ANFLOW column was estimated as follows:

<u>Method of removal</u>	<u>Mass of sludge dumped, kg (dry)</u>
Discharge port at bottom of the reactor, prior to packing removal	~1200
Packing removal	~1500
Remaining in lower conical section after packing removal	<u>~2800</u>
Total solids accumulated in the reactor	<u>~5500 kg</u>

These data are in reasonable agreement with the computer program and measured bioreactor weight estimates of ~7000 kg of total accumulated solids.

Samples of solids from the bottom of the ANFLOW column were analyzed for metals by induced coupled plasma (ICP) emission spectroscopy. The results from the ICP scan are given in Table 5.1.

The solids that accumulated in the ANFLOW bioreactor contained ~60% volatile solids. This agrees reasonably well with the 68% value that was estimated by the material balance model.

5.3 SITE RESTORATION

The contractual agreement between the Oak Ridge National Laboratory and the City of Knoxville, Tennessee required the restoration of the grounds that were altered by the installation of the ANFLOW Pilot Plant. The site restoration entails the following:

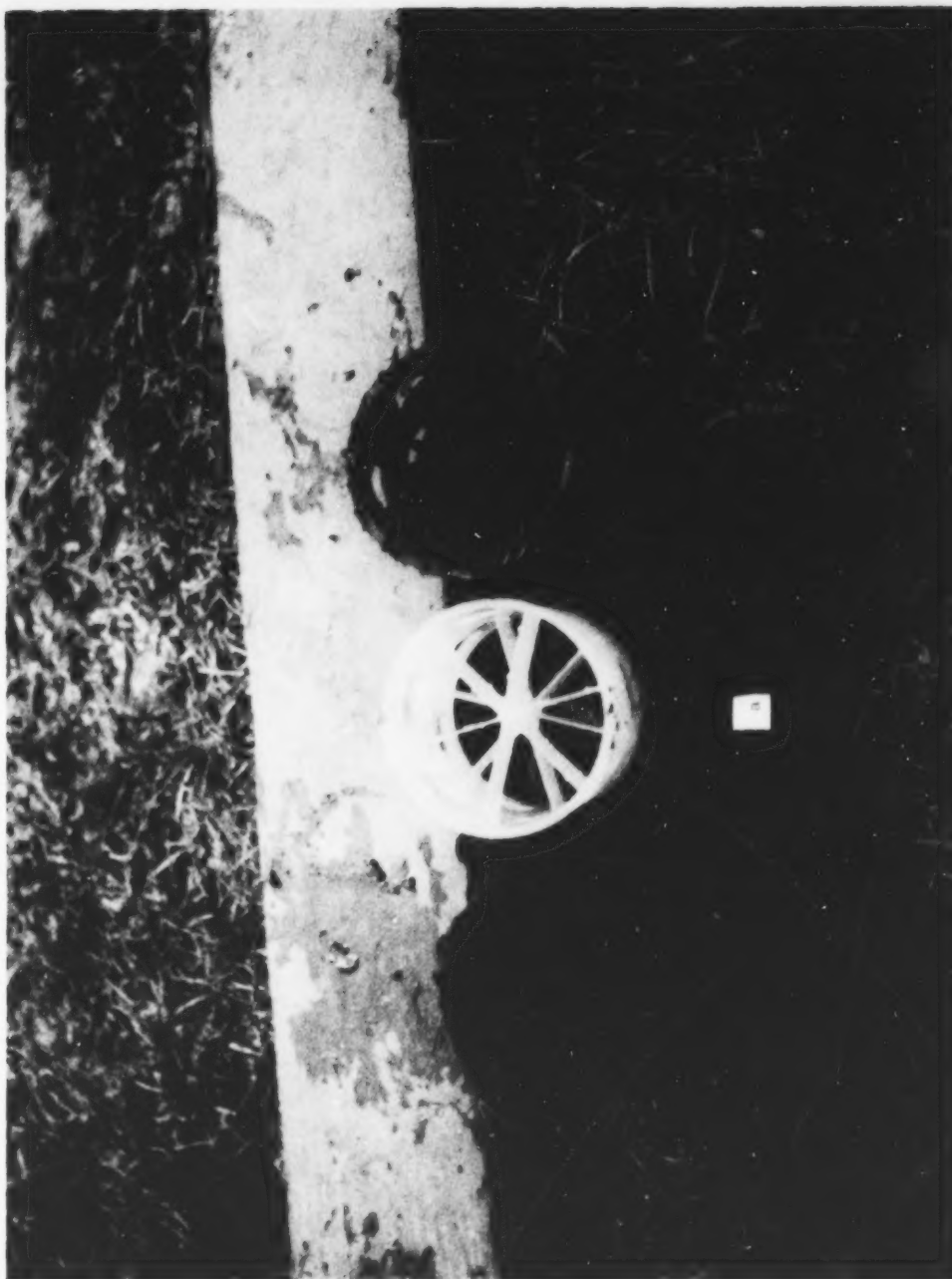


Fig. 5.3. (a) Packing before and after 806 d of operation.
(b) Packing after rinsing with water from hose.

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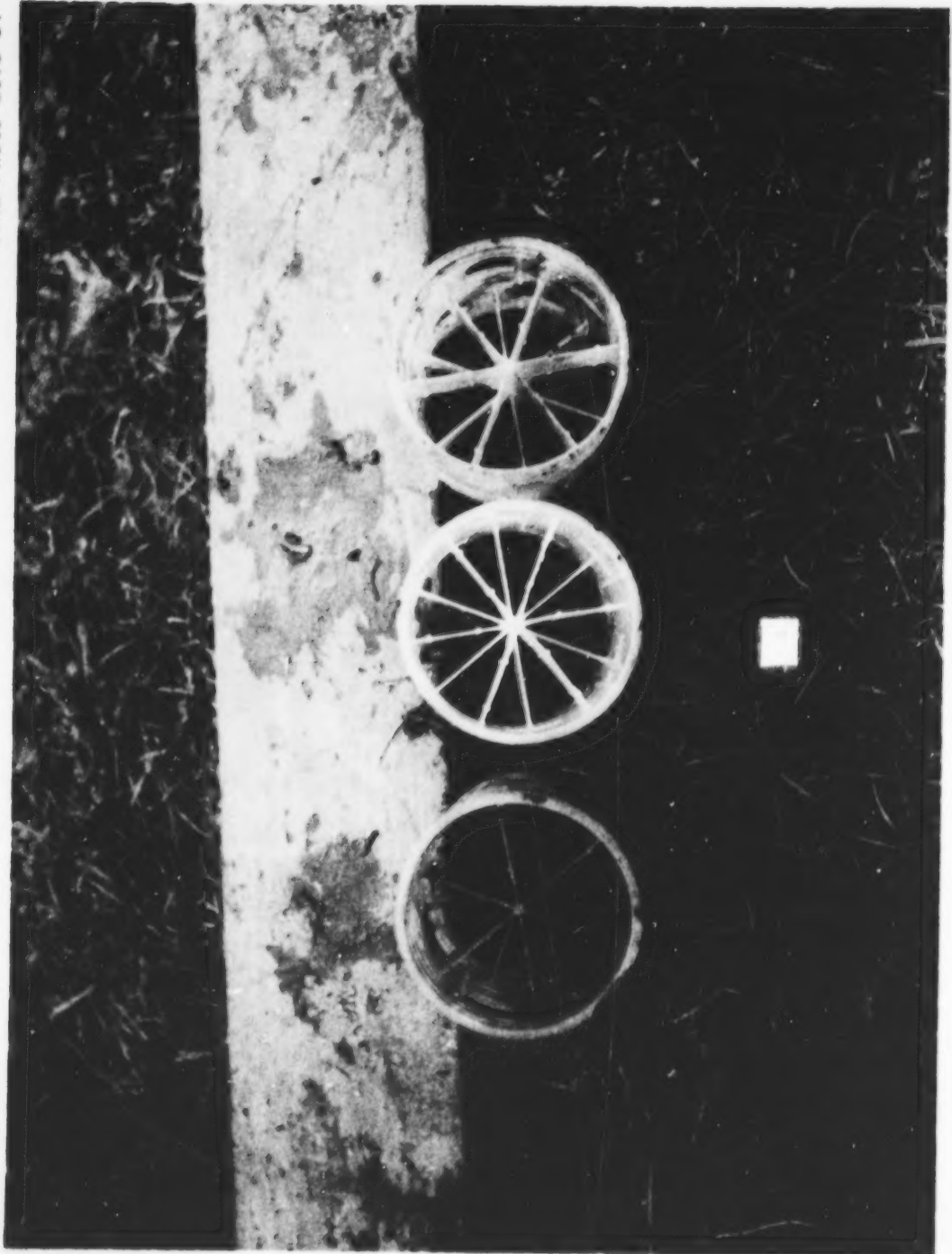


Table 5.1. Metals detected in sludge sample
from the ANFLOW column

Metal	Concentration (mg/kg)
Ag	3.1
Al	3100.
B	0.96
Ba	49.0
Be	<0.0098
Ca	1500.
Cd	0.83
Co	0.27
Cr	3.8
Cu	30.
Fe	1800.
Ga	<0.53
Hf	0.44
Mg	360.
Mn	13.
Mo	1.6
Na	170.
Ni	1.1
Pb	7.8
Sb	<1.1
Se	<3.3
Si	<0.91
Sr	8.4
Ti	180.
V	3.
Zn	140.
Zr	2.6
P	1100.

- Removal of ANFLOW building, ANFLOW column, and all associated piping, pumps, valves, instrumentation, and electrical appurtenances.
- Removal of reinforced concrete building slab and its associated base material, replacement of surface to the elevation of the adjacent contour, and reestablishment of grass cover following accepted practices.

These procedures have been completed.

6. STATUS OF ANFLOW TECHNOLOGY

6.1 CONCLUSIONS

The ANFLOW process has been operated successfully at the laboratory, 19 m³/d, and 190 m³/d (50,000 gpd) scale. A commercial ANFLOW unit of the latter size could handle the municipal wastewater produced by 250 to 500 people. Larger systems could be constructed using this basic module. Performance over this range has been consistent and predictable; no scale-up problems have been encountered. During treatment of low-strength municipal wastewater before primary sedimentation (TSS and BOD typically 100 mg/L each), the effluent has met the EPA secondary treatment discharge limits of 30 mg/L for TSS and BOD the vast majority of the time, with only an occasional increase to the 30 to 40 mg/L range for a brief period of time (perhaps 1 to 2 d). Loading rates were ~0.25 kg/m³·d of TSS and BOD each, and the hydraulic retention time was 9 to 10 h.

This performance was maintained in ambient cold-weather tests (~12°C water temperature), although the rate of solids accumulation in the bioreactor was higher in cold weather because of decreased biological activity, which normally converts solids to off-gas. These solids can be digested later during the warm-weather operation.

The primary mechanism for removal of TSS and BOD appears to be biophysical filtration. Over the 2-year period of operation of the 190 m³/d pilot plant in Knoxville, ~20% of the influent carbon was converted to methane, while 30% remained in the bioreactor as sludge. The balance of the carbon was converted to CO₂ or remained in the liquid effluent as TSS and BOD/COD. Over half of the methane was dissolved in the effluent water; this methane could potentially be recovered along with the methane in the off-gas.

The rate of accumulation of dry solids in the bioreactor is ~150 kg/3800 m³ (million gal) of wastewater treated. The rate is slightly higher in cold weather and somewhat lower in warm weather. This solids production rate may be compared to ~650 to 700 kg/3800 m³ from weak wastewater treated by primary sedimentation and activated sludge or trickling filtration (ref. 24, p. 583). Thus, the ANFLOW process shows a 75 to 80% reduction in solids production. A simple material balance model

was shown to predict the sludge accumulation using measurable influent and effluent parameters.

A brief campaign with higher-strength wastewater indicated that gas production does increase at higher loading rates. Solids accumulation also increased, probably due in part to the high solids content of the wastewater, which was formulated by mixing primary clarifier underflow with the raw wastewater. Performance of the ANFLOW process in terms of effluent water quality under these conditions is ambiguous, however, because the bioreactor was heavily loaded with accumulated solids when this test was run.

Discharge of solids was carried out several times late in the project. Simple draining of the bioreactor will remove some solids, but not as much as would probably be desired. Techniques need to be developed to improve the solids discharge procedures. Solids can be dislodged from the packing very easily by a gentle stream of water from a hose, as was demonstrated when the pilot plant was decommissioned.

The ANFLOW process is an energy conserving technology. Earlier studies^{21,22} have indicated that at the 3800 m³/d (1 mgd) scale, a treatment plant utilizing the ANFLOW process would require only 60% of the energy required for a plant utilizing activated sludge to treat weak wastewaters and only 30% to treat strong wastewaters. When only the biotreatment step is considered, ANFLOW is projected to require <10% of the energy required by activated sludge. Methane recovery is not included in these comparisons; however, recovery of methane and conversion to electricity at 40% efficiency is projected to provide more than sufficient energy to operate the ANFLOW-based treatment plant.

6.2 RECOMMENDATIONS

There are several areas in which more development work would help to establish the advantages of the ANFLOW process and accelerate commercialization of this technology. More extensive operation with higher-strength wastewaters is needed. Methane production would undoubtedly increase, and methane recovery would become more attractive. Solids discharge methods need to be improved, and operation over several cycles of accumulation and discharge needs to be demonstrated in order to

establish an optimal cycle time. The maximum hydraulic loading rate that can be handled while maintaining effluent quality has not been determined; this will be important with respect to normal diurnal flow variations. Finally, the cost of the packing material is a significant portion of the total capital cost. Experimental studies should be done with alternate packings of a higher specific surface area yet high void volume. It may be possible to increase the volumetric reaction rates and, hence, decrease the volume of packing.

7. ACKNOWLEDGMENTS

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APPENDIX A: CHARACTERISTICS OF INFLUENT WASTEWATER

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	BODS (MG/L)	COD (MG/L)	VSS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	V. ACTS (MG/L)	BODS-S (MG/L)	COD-S (MG/L)	FLOW (L/MIN)
10/ 1/82	422	21.00	6.70	120.00	168.00	55.00	64.00	206.00	*****	84.00	21.00	68.00	133.00
10/ 2/82	423	*****	*****	133.00	*****	*****	*****	*****	*****	*****	21.00	*****	132.00
10/ 3/82	424	*****	*****	137.30	*****	*****	*****	*****	*****	*****	17.00	*****	133.00
10/ 4/82	425	21.00	6.90	97.00	168.00	69.00	82.00	204.00	*****	96.00	11.00	49.00	135.00
10/ 5/82	426	20.00	7.00	80.00	*****	63.00	72.00	212.00	*****	89.00	11.00	*****	134.00
10/ 6/82	427	*****	*****	110.00	*****	*****	*****	*****	*****	*****	10.00	*****	134.00
10/ 7/82	428	21.00	6.90	130.00	166.00	76.00	89.00	207.00	*****	106.00	9.00	49.00	134.00
10/ 8/82	429	21.00	7.00	122.00	185.00	64.00	78.00	204.00	*****	77.00	19.00	55.00	133.00
10/ 9/82	430	*****	*****	128.00	*****	*****	*****	*****	*****	*****	8.00	*****	134.00
10/10/82	431	*****	*****	90.00	*****	*****	*****	*****	*****	*****	17.00	*****	133.00
10/11/82	432	21.00	6.90	130.00	170.00	65.00	85.00	194.00	*****	113.00	25.00	58.00	132.00
10/12/82	433	21.00	6.80	107.00	156.00	59.00	69.00	196.00	*****	70.00	13.00	53.00	132.00
10/13/82	434	21.00	6.90	78.00	160.00	71.00	93.00	168.00	*****	65.00	15.00	61.00	133.00
10/14/82	435	20.00	6.50	60.00	100.00	39.00	50.00	177.00	*****	62.00	28.00	27.00	133.00
10/15/82	436	20.00	6.90	173.00	72.00	24.00	30.00	193.00	*****	65.00	18.00	24.00	133.00
10/16/82	437	*****	*****	108.00	*****	*****	*****	*****	*****	*****	14.00	*****	134.00
10/17/82	438	*****	*****	76.00	*****	*****	*****	*****	*****	*****	14.00	*****	134.00
10/18/82	439	20.00	6.90	77.00	147.00	66.00	75.00	211.00	*****	64.00	6.00	32.00	132.00
10/19/82	440	19.00	7.00	107.00	106.00	46.00	51.00	195.00	*****	84.00	9.00	27.00	135.00
10/20/82	441	19.00	6.70	100.00	145.00	64.00	73.00	197.00	*****	140.00	2.00	61.00	137.00
10/21/82	442	*****	*****	103.00	*****	*****	*****	*****	*****	*****	8.00	*****	132.00
10/22/82	443	19.00	6.80	240.00	139.00	64.00	74.00	191.00	*****	65.00	14.00	22.00	133.00
10/23/82	444	*****	*****	100.00	*****	*****	*****	*****	*****	*****	9.00	*****	131.00
10/24/82	445	*****	*****	60.00	*****	*****	*****	*****	*****	*****	10.00	*****	130.00
10/25/82	446	18.00	7.00	150.00	211.00	88.00	101.00	201.00	*****	95.00	8.00	62.00	131.00
10/26/82	447	18.00	6.90	84.00	400.00	189.00	243.00	206.00	*****	81.00	9.00	70.00	132.00
10/27/82	448	19.00	7.00	137.00	385.00	171.00	216.00	216.00	*****	83.00	16.00	69.00	132.00
10/28/82	449	19.00	6.90	120.00	233.00	92.00	120.00	200.00	*****	86.00	9.00	79.00	132.00
10/29/82	450	19.00	7.00	106.00	185.00	64.00	72.00	197.00	*****	116.00	11.00	79.00	130.00
10/30/82	451	*****	*****	111.00	*****	*****	*****	*****	*****	*****	10.00	*****	132.00
10/31/82	452	*****	*****	54.00	*****	*****	*****	*****	*****	*****	16.00	*****	132.00

SUMMARY:

HIGH	21.00	7.00	240.00	400.00	189.00	243.00	216.00	0.00	140.00	28.00	79.00	137.00
LOW	18.00	6.50	38.00	72.00	24.00	30.00	168.00	0.00	62.00	2.00	22.00	130.00
AVERAGE	19.84	6.88	106.06	183.11	75.21	91.42	198.68	0.00	86.37	13.16	52.50	132.81
STD. DEV.	1.07	0.13	38.27	85.12	40.09	52.58	11.60	0.00	20.94	5.71	18.76	1.47
NO. OF POINTS	19.00	19.00	31.00	18.00	19.00	19.00	19.00	1.00	19.00	31.00	18.00	31.00

DATE	DAYS SINCE INOCULATION	TEMP. (C)	PH	BOD5 (MG/L)	COD (MG/L)	USS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	U.ACIDIS (MG/L)	BOD5-S (MG/L)	COD-S (MG/L)	FLOW (L/MIN)
11/ 1/82	453	*****	*****	81.00	*****	*****	*****	*****	*****	*****	*****	*****	132.00
11/ 2/82	454	19.00	6.80	110.00	78.00	31.00	31.00	158.00	*****	67.00	*****	27.00	132.00
11/ 3/82	455	19.00	6.90	58.00	151.00	58.00	69.00	181.00	*****	69.00	*****	45.00	130.00
11/ 4/82	456	19.00	6.80	93.00	128.00	46.00	54.00	163.00	5.00	84.00	*****	39.00	132.00
11/ 5/82	457	18.00	7.10	147.00	145.00	58.00	65.00	199.00	*****	93.00	*****	54.00	132.00
11/ 6/82	458	*****	*****	100.00	*****	*****	*****	*****	*****	*****	*****	*****	141.00
11/ 7/82	459	*****	*****	73.00	*****	*****	*****	*****	*****	*****	*****	*****	130.00
11/ 8/82	460	18.00	7.00	69.00	144.00	45.00	51.00	206.00	*****	98.00	*****	62.00	131.00
11/ 9/82	461	18.00	7.00	72.00	134.00	51.00	58.00	202.00	*****	92.00	*****	43.00	130.00
11/10/82	462	17.00	7.00	87.00	149.00	56.00	66.00	189.00	*****	*****	*****	43.00	131.00
11/11/82	463	18.00	7.00	75.00	144.00	58.00	68.00	191.00	*****	118.00	*****	39.00	132.00
11/12/82	464	18.00	7.00	82.00	136.00	51.00	56.00	198.00	*****	*****	*****	65.00	130.00
11/13/82	465	*****	*****	70.00	*****	*****	*****	*****	*****	*****	*****	*****	103.00
11/14/82	466	*****	*****	92.00	*****	*****	*****	*****	*****	*****	*****	*****	130.00
11/15/82	467	*****	*****	98.00	*****	*****	*****	*****	*****	*****	*****	*****	*****
11/16/82	468	*****	*****	59.00	*****	*****	*****	*****	*****	*****	*****	*****	*****
11/17/82	469	17.00	*****	58.00	156.00	73.00	78.00	193.00	*****	*****	*****	56.00	*****
11/18/82	470	17.00	7.10	120.00	121.00	45.00	45.00	194.00	*****	62.00	*****	57.00	*****
11/19/82	471	17.00	7.00	60.00	172.00	74.00	96.00	170.00	*****	74.00	*****	74.00	130.00
11/20/82	472	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	131.00
11/21/82	473	*****	*****	67.00	*****	*****	*****	*****	*****	*****	*****	*****	130.00
11/22/82	474	17.00	6.90	45.00	162.00	63.00	78.00	198.00	*****	64.00	*****	51.00	132.00
11/23/82	475	*****	*****	167.00	*****	*****	*****	*****	*****	*****	*****	*****	132.00
11/24/82	476	*****	*****	105.00	*****	*****	*****	*****	*****	*****	*****	*****	131.00
11/25/82	477	*****	*****	120.00	*****	*****	*****	*****	*****	*****	*****	*****	*****
11/26/82	478	*****	*****	87.00	*****	*****	*****	*****	*****	*****	*****	*****	*****
11/27/82	479	*****	*****	79.00	*****	*****	*****	*****	*****	*****	*****	*****	*****
11/28/82	480	*****	*****	53.00	*****	*****	*****	*****	*****	*****	*****	*****	131.00
11/29/82	481	16.00	6.80	36.00	125.00	44.00	61.00	172.00	*****	70.00	*****	43.00	130.00
11/30/82	482	16.00	6.80	60.00	83.00	29.00	38.00	*****	*****	*****	*****	38.00	131.00

SUMMARY:

HIGH	19.00	7.10	167.00	172.00	74.00	96.00	206.00	0.00	140.00	0.00	74.00	141.00
LOW	16.00	6.80	36.00	78.00	29.00	31.00	158.00	0.00	62.00	0.00	27.00	103.00
AVERAGE	17.60	6.94	83.55	135.20	52.13	60.93	186.00	0.00	85.92	0.00	49.07	130.17
STD. DEV.	0.99	0.11	29.39	26.12	12.93	16.53	14.91	0.00	23.90	0.00	12.31	6.20
NO. OF POINTS	15.00	14.00	29.00	15.00	15.00	15.00	14.00	1.00	12.00	0.00	15.00	24.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	pH	ROB5 (MG/L)	COB (MG/L)	USS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	U.ACL. (MG/L)	DO (MG/L)	COB-S (MG/L)	FLOW (L/MIN)
12/ 1/82	483	16.00	6.90	35.00	132.00	43.00	62.00	*****	177.00	*****	79.00	39.00	200.00
12/ 2/82	484	16.00	6.80	38.00	84.00	29.00	43.00	155.00	*****	109.00	*****	35.00	112.00
12/ 3/82	485	*****	*****	63.00	*****	*****	*****	*****	*****	*****	*****	*****	*****
12/ 4/82	486	*****	*****	35.00	*****	*****	*****	*****	*****	*****	*****	*****	140.00
12/ 5/82	487	*****	*****	75.00	*****	*****	*****	*****	*****	*****	*****	*****	40.00
12/ 6/82	488	16.00	6.80	40.00	126.00	58.00	92.00	161.00	*****	96.00	*****	40.00	130.00
12/ 7/82	489	16.00	6.80	42.00	87.00	28.00	31.00	186.00	2.00	106.00	*****	39.00	132.00
12/ 8/82	490	16.00	*****	42.00	68.00	21.00	24.00	181.00	*****	77.00	*****	32.00	134.00
12/ 9/82	491	16.00	6.90	47.00	83.00	25.00	28.00	193.00	6.00	91.00	*****	43.00	132.00
12/10/82	492	16.00	6.90	48.00	121.00	29.00	31.00	199.00	*****	89.00	*****	38.00	129.00
12/11/82	493	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	125.00
12/12/82	494	*****	*****	49.00	*****	*****	*****	*****	*****	*****	*****	*****	131.00
12/13/82	495	*****	*****	47.00	*****	*****	*****	*****	*****	*****	*****	*****	130.00
12/14/82	496	15.00	6.90	57.00	90.00	27.00	34.00	191.00	7.00	89.00	*****	36.00	131.00
12/15/82	497	15.00	6.90	52.00	102.00	10.00	16.00	187.00	*****	96.00	*****	43.00	130.00
12/16/82	498	14.00	6.80	42.00	98.00	40.00	55.00	163.00	6.00	93.00	*****	25.00	130.00
12/17/82	499	14.00	6.90	69.00	98.00	13.00	17.00	171.00	*****	103.00	*****	25.00	132.00
12/18/82	500	*****	*****	76.00	*****	*****	*****	*****	*****	*****	*****	*****	124.00
12/19/82	501	*****	*****	40.00	*****	*****	*****	*****	*****	*****	*****	*****	165.00
12/20/82	502	14.00	6.90	55.00	79.00	23.00	28.00	174.00	*****	151.00	*****	30.00	132.00
12/21/82	503	14.00	6.90	64.00	101.00	39.00	42.00	223.00	*****	94.00	*****	51.00	150.00
12/22/82	504	*****	*****	67.00	*****	*****	*****	*****	*****	*****	*****	*****	132.00
12/23/82	505	*****	*****	59.00	*****	*****	*****	*****	*****	*****	*****	*****	132.00
12/24/82	506	*****	*****	68.00	*****	*****	*****	*****	*****	*****	*****	*****	130.00
12/25/82	507	*****	*****	51.00	*****	*****	*****	*****	*****	*****	*****	*****	130.00
12/26/82	508	*****	*****	63.00	*****	*****	*****	*****	*****	*****	*****	*****	134.00
12/27/82	509	*****	*****	76.00	106.00	39.00	44.00	197.00	*****	*****	*****	45.00	128.00
12/28/82	510	15.00	6.90	31.00	234.00	103.00	129.00	205.00	*****	*****	*****	50.00	128.00
12/29/82	511	*****	*****	36.00	*****	*****	*****	*****	*****	*****	*****	*****	0.00
12/30/82	512	*****	*****	49.00	*****	*****	*****	*****	*****	*****	*****	*****	300.00
12/31/82	513	*****	*****	110.00	*****	*****	*****	*****	*****	*****	*****	*****	128.00

SUMMARY:

HIGH	16.00	6.90	110.00	234.00	103.00	129.00	223.00	177.00	151.00	0.00	51.00	300.00
LOW	14.00	6.80	31.00	68.00	10.00	16.00	155.00	2.00	77.00	0.00	25.00	40.00
AVERAGE	15.21	6.87	54.20	107.27	35.13	45.07	184.71	39.60	99.50	0.00	38.07	136.93
STD. DEV.	0.89	0.05	16.90	39.31	22.37	30.27	18.77	76.83	18.32	0.00	7.88	39.05
NO. OF POINTS	14.00	13.00	30.00	15.00	15.00	15.00	14.00	5.00	12.00	1.00	15.00	29.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	RODS (MG/L)	COB (MG/L)	USS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	V. ACIDS (MG/L)	RODS-S (MG/L)	COD-S (MG/L)	FLOW (L/MIN)
1/1/83	514	*****	*****	67.00	*****	*****	*****	*****	*****	*****	22.00	*****	130.00
1/2/83	515	*****	*****	58.00	*****	*****	*****	*****	*****	*****	7.00	*****	128.00
1/3/83	516	*****	*****	68.00	*****	*****	*****	*****	*****	*****	10.00	*****	129.00
1/4/83	517	14.00	6.90	58.00	*****	40.00	44.00	201.00	6.00	58.00	5.00	*****	130.00
1/5/83	518	14.00	7.00	60.00	174.00	48.00	59.00	201.00	*****	82.00	24.00	56.00	132.00
1/6/83	519	14.00	6.90	58.00	121.00	40.00	46.00	237.00	*****	79.00	22.00	50.00	129.00
1/7/83	520	14.00	7.00	112.00	96.00	27.00	31.00	190.00	*****	82.00	18.00	43.00	142.00
1/8/83	521	*****	*****	70.00	*****	*****	*****	*****	*****	*****	11.00	*****	130.00
1/9/83	522	*****	*****	50.00	*****	*****	*****	*****	*****	*****	11.00	*****	130.00
1/10/83	523	*****	*****	47.00	*****	*****	*****	*****	*****	*****	7.00	*****	115.00
1/11/83	524	14.00	7.00	64.00	87.00	27.00	31.00	182.00	*****	64.00	2.00	42.00	132.00
1/12/83	525	13.00	6.90	74.00	106.00	34.00	42.00	184.00	*****	70.00	4.00	35.00	133.00
1/13/83	526	13.00	6.90	90.00	111.00	31.00	37.00	193.00	*****	219.00	8.00	46.00	133.00
1/14/83	527	*****	*****	98.00	*****	*****	*****	*****	*****	*****	14.00	*****	*****
1/15/83	528	*****	*****	80.00	*****	*****	*****	*****	*****	*****	11.00	*****	133.00
1/16/83	529	*****	*****	99.00	*****	*****	*****	*****	*****	*****	6.00	*****	133.00
1/17/83	530	13.00	7.00	98.00	155.00	52.00	57.00	226.00	*****	*****	23.00	78.00	132.00
1/18/83	531	13.00	6.80	90.00	184.00	75.00	91.00	211.00	*****	*****	9.00	55.00	130.00
1/19/83	532	*****	*****	98.00	*****	*****	*****	*****	*****	*****	14.00	*****	133.00
1/20/83	533	13.00	7.00	66.00	232.00	95.00	119.00	242.00	*****	*****	7.00	60.00	133.00
1/21/83	534	*****	*****	70.00	*****	*****	*****	*****	*****	*****	18.00	*****	133.00
1/22/83	535	*****	*****	82.00	*****	*****	*****	*****	*****	*****	14.00	*****	133.00
1/23/83	536	*****	*****	90.00	*****	*****	*****	*****	*****	*****	8.00	*****	133.00
1/24/83	537	13.00	7.00	71.00	121.00	36.00	41.00	199.00	*****	467.00	13.00	53.00	133.00
1/25/83	538	13.00	6.90	100.00	135.00	39.00	45.00	267.00	*****	*****	8.00	61.00	135.00
1/26/83	539	*****	*****	82.00	*****	*****	*****	*****	*****	*****	12.00	*****	133.00
1/27/83	540	13.00	7.00	69.00	199.00	72.00	83.00	239.00	*****	*****	13.00	57.00	133.00
1/28/83	541	13.00	7.10	72.00	142.00	51.00	60.00	202.00	*****	*****	14.00	64.00	134.00
1/29/83	542	*****	*****	88.00	*****	*****	*****	*****	*****	*****	14.00	*****	132.00
1/30/83	543	*****	*****	68.00	*****	*****	*****	*****	*****	*****	10.00	*****	132.00
1/31/83	544	13.00	7.00	71.00	149.00	45.00	51.00	203.00	*****	7.00	7.00	62.00	133.00

SUMMARY:

HIGH	14.00	7.10	112.00	232.00	95.00	119.00	267.00	0.00	467.00	24.00	78.00	142.00
LOW	13.00	6.80	47.00	87.00	27.00	31.00	182.00	0.00	7.00	2.00	35.00	115.00
AVERAGE	13.33	6.96	76.39	143.71	47.47	55.80	211.80	0.00	125.33	11.81	54.43	131.70
STD. DEV.	0.49	0.07	16.39	41.73	19.39	24.45	24.78	0.00	139.99	5.70	10.90	4.01
NO. OF POINTS	15.00	15.00	31.00	14.00	15.00	15.00	15.00	1.00	9.00	31.00	14.00	30.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	RODS (MG/L)	COB (MG/L)	USS (MG/L)	ISS (MG/L)	ALK (MG/L)	NH4 (MG/L)	U-ACIDS (MG/L)	RODS-S (MG/L)	COB-S (MG/L)	FLOW (L/HIN)
2/ 1/83													
2/ 1/83	545	13.00	6.90	80.00	146.00	50.00	59.00	204.00	*****	*****	15.00	59.00	133.00
2/ 2/83	546	13.00	6.80	51.00	236.00	97.00	137.00	173.00	*****	*****	25.00	67.00	132.00
2/ 3/83	547	13.00	7.20	47.00	114.00	42.00	53.00	163.00	2.00	*****	14.00	47.00	132.00
2/ 4/83	548	13.00	6.80	94.00	110.00	*****	*****	180.00	*****	*****	15.00	58.00	132.00
2/ 5/83	549	*****	*****	68.00	*****	*****	*****	*****	*****	*****	14.00	*****	132.00
2/ 6/83	550	*****	*****	58.00	*****	*****	*****	*****	*****	*****	14.00	*****	132.00
2/ 7/83	551	12.00	6.90	49.00	105.00	30.00	31.00	162.00	*****	*****	19.00	60.00	132.00
2/ 8/83	552	*****	*****	90.00	*****	*****	*****	*****	*****	*****	12.00	*****	132.00
2/ 9/83	553	12.00	6.80	50.00	106.00	30.00	36.00	186.00	*****	*****	11.00	49.00	132.00
2/10/83	554	12.00	7.00	47.00	*****	48.00	57.00	*****	*****	*****	7.00	*****	130.00
2/11/83	555	12.00	6.80	64.00	132.00	44.00	57.00	157.00	*****	*****	2.00	43.00	132.00
2/12/83	556	*****	*****	74.00	*****	*****	*****	*****	*****	*****	4.00	*****	132.00
2/13/83	557	*****	*****	90.00	*****	*****	*****	*****	*****	*****	8.00	*****	133.00
2/14/83	558	12.00	7.00	98.00	97.00	*****	*****	176.00	*****	*****	14.00	42.00	132.00
2/15/83	559	*****	*****	80.00	*****	*****	*****	*****	*****	*****	11.00	*****	132.00
2/16/83	560	13.00	6.90	99.00	119.00	33.00	38.00	192.00	*****	*****	6.00	53.00	133.00
2/17/83	561	13.00	7.00	98.00	*****	50.00	51.00	*****	*****	*****	23.00	*****	133.00
2/18/83	562	*****	*****	90.00	*****	*****	*****	*****	*****	*****	9.00	*****	132.00
2/19/83	563	*****	*****	98.00	*****	*****	*****	*****	*****	*****	14.00	*****	132.00
2/20/83	564	*****	*****	66.00	*****	*****	*****	*****	*****	*****	7.00	*****	132.00
2/21/83	565	*****	*****	70.00	*****	*****	*****	*****	*****	*****	18.00	*****	132.00
2/22/83	566	*****	*****	82.00	*****	*****	*****	*****	*****	*****	14.00	*****	132.00
2/23/83	567	12.00	6.90	90.00	145.00	57.00	68.00	172.00	12.00	*****	8.00	53.00	132.00
2/24/83	568	13.00	*****	71.00	*****	61.00	72.00	*****	*****	*****	13.00	*****	132.00
2/25/83	569	12.00	7.20	100.00	*****	51.00	59.00	175.00	*****	*****	8.00	*****	132.00
2/26/83	570	*****	*****	82.00	*****	*****	*****	*****	*****	*****	12.00	*****	132.00
2/27/83	571	*****	*****	69.00	*****	*****	*****	*****	*****	*****	13.00	*****	132.00
2/28/83	572	12.00	7.00	72.00	152.00	49.00	53.00	204.00	*****	*****	14.00	57.00	133.00

SUMMARY:

HIGH	13.00	7.20	100.00	236.00	97.00	137.00	204.00	12.00	0.00	25.00	67.00	133.00
LOW	12.00	6.80	47.00	97.00	30.00	31.00	157.00	2.00	0.00	2.00	42.00	130.00
AVERAGE	12.40	6.94	75.96	132.73	49.38	59.31	178.67	7.00	0.00	12.29	53.45	132.11
STD. DEV.	0.51	0.13	17.47	36.90	17.25	26.19	15.39	7.07	0.00	5.20	7.70	0.57
NO. OF POINTS	15.00	14.00	28.00	11.00	13.00	13.00	12.00	2.00	0.00	28.00	11.00	28.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	RODS (MG/L)	COB (MG/L)	USS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	U.ACTINS (MG/L)	RODS-S (MG/L)	COD-S (MG/L)	FLOW (L/HN)
3/ 1/83	573	*****	*****	96.00	*****	*****	*****	*****	*****	*****	13.00	*****	133.00
3/ 2/83	574	13.00	*****	83.00	79.00	94.00	94.00	207.00	*****	*****	12.00	67.00	132.00
3/ 3/83	575	13.00	7.10	91.00	63.00	69.00	69.00	207.00	10.00	*****	14.00	*****	132.00
3/ 4/83	576	14.00	*****	124.00	74.00	93.00	93.00	188.00	*****	*****	16.00	54.00	132.00
3/ 5/83	577	*****	*****	120.00	*****	*****	*****	*****	*****	*****	17.00	*****	132.00
3/ 6/83	578	*****	*****	94.00	*****	*****	*****	*****	*****	*****	14.00	*****	133.00
3/ 7/83	579	14.00	7.10	76.00	156.00	47.00	55.00	185.00	*****	*****	7.00	66.00	132.00
3/ 8/83	580	*****	*****	77.00	*****	*****	*****	*****	*****	*****	23.00	*****	132.00
3/ 9/83	581	14.00	7.00	60.00	159.00	60.00	67.00	187.00	*****	*****	9.00	44.00	132.00
3/10/83	582	14.00	7.00	80.00	*****	59.00	72.00	*****	10.00	*****	6.00	*****	132.00
3/11/83	583	*****	*****	78.00	*****	*****	*****	*****	*****	*****	11.00	*****	132.00
3/12/83	584	*****	*****	108.00	*****	*****	*****	*****	*****	*****	14.00	*****	133.00
3/13/83	585	*****	*****	80.00	*****	*****	*****	*****	*****	*****	8.00	*****	*****
3/14/83	586	14.00	*****	84.00	*****	55.00	55.00	180.00	*****	*****	10.00	*****	132.00
3/15/83	587	14.00	*****	102.00	59.00	66.00	66.00	187.00	*****	*****	8.00	*****	132.00
3/16/83	588	*****	*****	77.00	*****	*****	*****	*****	*****	*****	10.00	*****	132.00
3/17/83	589	18.00	7.00	78.00	192.00	68.00	75.00	*****	8.00	0.00	10.00	67.00	132.00
3/18/83	590	18.00	6.90	94.00	143.00	66.00	76.00	180.00	*****	*****	12.00	51.00	132.00
3/19/83	591	*****	*****	94.00	*****	*****	*****	*****	*****	*****	7.00	*****	*****
3/20/83	592	*****	*****	80.00	*****	*****	*****	*****	*****	*****	11.00	*****	132.00
3/21/83	593	18.00	6.90	77.00	148.00	52.00	64.00	161.00	*****	*****	9.00	52.00	132.00
3/22/83	594	*****	*****	88.00	*****	*****	*****	*****	*****	*****	7.00	*****	132.00
3/23/83	595	18.00	*****	82.00	190.00	69.00	79.00	170.00	*****	*****	9.00	74.00	132.00
3/24/83	596	18.00	6.90	82.00	*****	50.00	57.00	*****	8.00	*****	7.00	*****	132.00
3/25/83	597	18.00	*****	112.00	211.00	82.00	101.00	171.00	*****	*****	6.00	58.00	132.00
3/26/83	598	*****	*****	122.00	*****	*****	*****	*****	*****	*****	16.00	*****	133.00
3/27/83	599	*****	*****	79.00	*****	*****	*****	*****	*****	*****	7.00	*****	133.00
3/28/83	600	18.00	6.90	92.00	130.00	55.00	69.00	164.00	*****	*****	11.00	51.00	134.00
3/29/83	601	*****	*****	90.00	*****	*****	*****	*****	*****	*****	6.00	*****	132.00
3/30/83	602	18.00	*****	76.00	120.00	40.00	42.00	*****	*****	*****	10.00	49.00	133.00
3/31/83	603	*****	*****	106.00	*****	*****	*****	*****	*****	*****	11.00	*****	*****

SUMMARY:

HIGH	18.00	7.10	124.00	211.00	82.00	101.00	207.00	10.00	0.00	0.00	23.00	74.00	134.00
LOW	13.00	6.90	60.00	120.00	40.00	42.00	161.00	8.00	0.00	0.00	6.00	44.00	132.00
AVERAGE	15.88	6.98	89.74	169.45	60.75	70.88	182.25	9.00	0.00	0.00	10.68	57.55	132.29
STD. DEV.	2.22	0.08	15.88	30.28	11.84	15.63	14.72	1.15	0.00	0.00	3.87	9.52	0.53
NO. OF POINTS	16.00	9.00	31.00	11.00	16.00	16.00	12.00	4.00	0.00	0.00	31.00	11.00	28.00

DATE	DAYS SINCE INOCULATION	TEMP (°C)	PH	ROBS (MG/L)	COD (MG/L)	USS (MG/L)	TSS (MG/L)	ALK (MG/L)	PH4 (MG/L)	V. ACTIDS (MG/L)	ROBS-S (MG/L)	COD-S (MG/L)	FLOW (L/MIN)
4/ 1/83	604	*****	*****	137.00	*****	*****	*****	*****	*****	*****	9.00	*****	133.00
4/ 2/83	605	*****	*****	123.00	*****	*****	*****	*****	*****	*****	18.00	*****	133.00
4/ 3/83	606	*****	*****	70.00	*****	*****	*****	*****	*****	*****	7.00	*****	133.00
4/ 4/83	607	18.00	6.90	76.00	175.00	57.00	65.00	174.00	*****	*****	7.00	71.00	133.00
4/ 5/83	608	18.00	6.70	72.00	*****	*****	*****	*****	*****	*****	23.00	*****	132.00
4/ 6/83	609	*****	*****	63.00	*****	*****	*****	*****	*****	*****	15.00	*****	70.00
4/ 7/83	610	21.00	6.20	56.00	*****	*****	*****	*****	*****	*****	12.00	*****	70.00
4/ 8/83	611	21.00	6.60	64.00	25.00	*****	25.00	*****	*****	*****	11.00	*****	70.00
4/ 9/83	612	*****	*****	42.00	77.00	*****	*****	*****	*****	*****	11.00	42.00	70.00
4/10/83	613	*****	*****	61.00	*****	*****	*****	*****	*****	*****	7.00	*****	70.00
4/11/83	614	20.00	6.30	70.00	*****	*****	*****	*****	*****	*****	6.00	*****	70.00
4/12/83	615	*****	*****	84.00	104.00	*****	*****	*****	*****	*****	9.00	34.00	70.00
4/13/83	616	*****	*****	75.00	*****	*****	*****	*****	*****	*****	6.00	*****	70.00
4/14/83	617	*****	*****	79.00	*****	*****	*****	*****	*****	*****	10.00	*****	70.00
4/15/83	618	*****	*****	58.00	158.00	57.00	76.00	169.00	*****	*****	7.00	53.00	70.00
4/16/83	619	*****	*****	64.00	*****	*****	*****	*****	*****	*****	10.00	*****	70.00
4/17/83	620	*****	*****	68.00	*****	*****	*****	*****	*****	*****	12.00	*****	70.00
4/18/83	621	*****	*****	74.00	137.00	46.00	48.00	*****	*****	*****	12.00	58.00	70.00
4/19/83	622	*****	*****	90.00	123.00	38.00	57.00	*****	*****	*****	5.00	54.00	72.00
4/20/83	623	*****	*****	68.00	*****	*****	*****	*****	*****	*****	10.00	*****	72.00
4/21/83	624	*****	*****	78.00	152.00	45.00	56.00	182.00	7.00	*****	9.00	58.00	72.00
4/22/83	625	*****	6.97	86.00	*****	*****	*****	*****	*****	*****	5.00	*****	72.00
4/23/83	626	*****	*****	80.00	*****	*****	*****	*****	*****	*****	18.00	*****	72.00
4/24/83	627	*****	*****	53.00	*****	*****	*****	*****	*****	*****	7.00	*****	72.00
4/25/83	628	*****	7.30	58.00	88.00	27.00	30.00	174.00	*****	*****	7.00	49.00	73.00
4/26/83	629	*****	*****	96.00	*****	*****	*****	*****	6.00	*****	7.00	*****	72.00
4/27/83	630	*****	7.20	70.00	182.00	56.00	80.00	182.00	*****	*****	9.00	73.00	73.00
4/28/83	631	*****	*****	70.00	*****	*****	*****	*****	*****	*****	4.00	*****	73.00
4/29/83	632	24.00	7.30	90.00	140.00	47.00	53.00	172.00	*****	*****	18.00	50.00	73.00
4/30/83	633	*****	*****	76.00	*****	*****	*****	*****	*****	*****	14.00	*****	73.00

SUMMARY:

HIGH	24.00	7.30	137.00	182.00	57.00	80.00	182.00	7.00	0.00	23.00	73.00	133.00
LOW	18.00	6.20	42.00	77.00	25.00	29.00	169.00	6.00	0.00	4.00	34.00	70.00
AVERAGE	20.33	6.83	75.03	133.60	44.22	54.89	175.50	6.50	0.00	10.17	54.20	81.43
STD. DEV.	2.25	6.41	19.11	35.46	12.15	17.77	5.36	0.71	0.00	4.55	11.87	23.39
NO. OF POINTS	6.00	9.00	30.00	10.00	9.00	9.00	6.00	2.00	0.00	30.00	10.00	30.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	RODS (MG/L)	COB (MG/L)	VSS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	U. ACTS (MG/L)	R005-S (MG/L)	COB-S (MG/L)	FLOW (L/MIN)
5/ 1/83	634	*****	*****	76.00	*****	*****	*****	*****	*****	*****	10.00	*****	81.00
5/ 2/83	635	24.00	7.30	64.00	145.00	53.00	54.00	175.00	*****	*****	7.00	51.00	82.00
5/ 3/83	636	*****	*****	72.00	*****	*****	*****	*****	*****	*****	7.00	*****	82.00
5/ 4/83	637	24.00	7.20	74.00	*****	45.00	53.00	169.00	*****	*****	7.00	*****	80.00
5/ 5/83	638	24.00	*****	70.00	*****	45.00	54.00	*****	6.00	*****	11.00	*****	82.00
5/ 6/83	639	*****	*****	94.00	*****	*****	*****	*****	*****	*****	9.00	*****	82.00
5/ 7/83	640	*****	*****	102.00	*****	*****	*****	*****	*****	*****	25.00	*****	83.00
5/ 8/83	641	*****	*****	74.00	*****	*****	*****	*****	*****	*****	8.00	*****	83.00
5/ 9/83	642	24.00	7.20	94.00	134.00	50.00	58.00	171.00	6.00	*****	10.00	48.00	83.00
5/10/83	643	*****	*****	140.00	*****	*****	*****	*****	*****	*****	16.00	*****	*****
5/11/83	644	*****	*****	114.00	*****	*****	*****	*****	*****	*****	7.00	*****	*****
5/12/83	645	*****	*****	89.00	*****	*****	*****	*****	*****	*****	13.00	*****	*****
5/13/83	646	*****	*****	121.00	*****	*****	*****	*****	*****	*****	18.00	*****	*****
5/14/83	647	*****	*****	74.00	*****	*****	*****	*****	*****	*****	17.00	*****	90.00
5/15/83	648	*****	*****	69.00	*****	*****	*****	*****	*****	*****	10.00	*****	95.00
5/16/83	649	24.00	7.30	76.00	147.00	48.00	55.00	185.00	*****	*****	10.00	73.00	96.00
5/17/83	650	24.00	7.30	70.00	*****	*****	*****	180.00	6.00	*****	10.00	*****	96.00
5/18/83	651	23.00	7.30	75.00	*****	44.00	46.00	*****	*****	*****	13.00	*****	96.00
5/19/83	652	23.00	*****	59.00	201.00	*****	*****	*****	*****	*****	17.00	76.00	98.00
5/20/83	653	*****	*****	64.00	*****	*****	*****	*****	*****	*****	17.00	*****	96.00
5/21/83	654	*****	*****	99.00	*****	*****	*****	*****	*****	*****	18.00	*****	58.00
5/22/83	655	*****	*****	42.00	*****	*****	*****	*****	*****	*****	12.00	*****	98.00
5/23/83	656	23.00	7.10	42.00	62.00	22.00	31.00	166.00	*****	*****	21.00	28.00	98.00
5/24/83	657	23.00	7.40	43.00	*****	*****	*****	*****	4.00	*****	11.00	*****	99.00
5/25/83	658	*****	*****	51.00	*****	*****	*****	*****	*****	*****	6.00	*****	98.00
5/26/83	659	*****	*****	41.00	*****	*****	*****	*****	*****	*****	9.00	*****	*****
5/27/83	660	*****	*****	63.00	*****	*****	*****	*****	*****	*****	9.00	*****	54.00
5/28/83	661	*****	*****	56.00	*****	*****	*****	*****	*****	*****	9.00	*****	73.00
5/29/83	662	*****	*****	44.00	*****	*****	*****	*****	*****	*****	11.00	*****	96.00
5/30/83	663	*****	*****	54.00	*****	*****	*****	*****	*****	*****	11.00	*****	96.00
5/31/83	664	*****	7.20	62.00	130.00	47.00	53.00	184.00	*****	*****	9.00	50.00	98.00

SUMMARY:

HIGH	24.00	7.40	140.00	201.00	53.00	58.00	185.00	6.00	0.00	0.00	25.00	76.00	99.00
LOW	23.00	7.10	41.00	62.00	22.00	31.00	166.00	4.00	0.00	0.00	6.00	28.00	54.00
AVERAGE	23.60	7.26	73.13	136.50	44.25	50.50	175.71	5.50	0.00	0.00	11.87	54.33	87.19
STD. DEV.	0.52	0.09	24.18	44.59	6.47	8.57	7.48	1.00	0.00	0.00	4.60	17.78	11.99
NO. OF POINTS	10.00	9.00	31.00	6.00	8.00	8.00	7.00	4.00	0.00	0.00	31.00	6.00	26.00

DATE	DAYS SINCE INOCULATION	TEMP. (C)	PH	ROB5 (MG/L)	COB (MG/L)	USS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	V. AC (US (MG/L)	ROB5-S (MG/L)	COB-S (MG/L)	FLOW (L/MIN)
6/ 1/83	665	17.00	6.90	86.00	111.00	38.00	40.00	*****	*****	*****	*****	43.00	31.00
6/ 2/83	666	17.00	7.30	99.00	294.00	*****	*****	199.00	*****	*****	*****	67.00	91.00
6/ 3/83	667	19.00	*****	144.00	*****	*****	*****	*****	*****	*****	*****	*****	87.00
6/ 4/83	668	17.00	*****	52.00	*****	*****	*****	*****	*****	*****	*****	*****	99.00
6/ 5/83	669	17.00	*****	44.00	*****	*****	*****	*****	*****	*****	*****	*****	93.00
6/ 6/83	670	18.00	*****	41.00	*****	*****	*****	*****	*****	*****	*****	*****	85.00
6/ 7/83	671	18.00	*****	38.00	*****	*****	*****	*****	*****	*****	*****	*****	1.00
6/ 8/83	672	18.00	*****	66.00	*****	*****	*****	*****	*****	*****	*****	*****	1.00
6/ 9/83	673	24.00	*****	53.00	*****	*****	*****	*****	*****	*****	*****	*****	86.00
6/10/83	674	24.00	7.00	80.00	153.00	54.00	66.00	*****	*****	*****	*****	64.00	89.00
6/11/83	675	23.00	*****	63.00	*****	*****	*****	*****	*****	*****	*****	*****	86.00
6/12/83	676	24.00	*****	56.00	*****	*****	*****	*****	*****	*****	*****	*****	86.00
6/13/83	677	24.00	7.40	*****	89.00	35.00	42.00	198.00	*****	*****	*****	30.00	86.00
6/14/83	678	30.00	6.90	*****	*****	*****	*****	*****	*****	*****	*****	*****	55.00
6/15/83	679	27.00	*****	*****	104.00	93.00	114.00	*****	*****	*****	*****	44.00	102.00
6/16/83	680	30.00	6.90	*****	*****	93.00	115.00	*****	*****	*****	*****	48.00	91.00
6/17/83	681	25.00	7.00	*****	410.00	93.00	*****	205.00	*****	*****	*****	*****	103.00
6/18/83	682	25.00	6.90	*****	*****	*****	*****	*****	*****	*****	*****	*****	102.00
6/19/83	683	30.00	6.80	*****	*****	*****	*****	*****	*****	*****	*****	*****	40.00
6/20/83	684	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	90.00
6/21/83	685	27.00	7.40	*****	198.00	*****	*****	*****	*****	*****	*****	113.00	50.00
6/22/83	686	22.00	7.10	*****	181.00	*****	*****	*****	*****	*****	*****	69.00	132.00
6/23/83	687	22.00	7.00	*****	254.00	122.00	135.00	*****	*****	*****	*****	84.00	132.00
6/24/83	688	22.00	7.00	*****	307.00	147.00	177.00	*****	*****	*****	*****	57.00	132.00
6/25/83	689	23.00	7.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	100.00
6/26/83	690	26.00	6.90	*****	*****	*****	*****	*****	*****	*****	*****	*****	99.00
6/27/83	691	22.00	6.90	*****	163.00	63.00	77.00	190.00	*****	*****	*****	54.00	99.00
6/28/83	692	22.00	6.80	*****	171.00	73.00	87.00	189.00	8.00	*****	*****	71.00	100.00
6/29/83	693	20.00	7.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	100.00
6/30/83	694	21.00	7.20	*****	167.00	65.00	85.00	198.00	*****	*****	*****	64.00	100.00

SUMMARY:

HIGH	30.00	7.40	144.00	410.00	147.00	177.00	205.00	0.00	0.00	0.00	0.00	113.00	132.00
LOW	17.00	6.80	38.00	89.00	35.00	40.00	189.00	0.00	0.00	0.00	0.00	30.00	1.00
AVERAGE	22.55	7.02	68.50	200.15	78.30	93.80	196.50	0.00	0.00	0.00	0.00	62.15	84.93
STD. DEV.	4.00	0.18	30.24	92.48	35.89	42.47	6.02	0.00	0.00	0.00	0.00	20.90	32.37
NO. OF POINTS	29.00	19.00	12.00	13.00	10.00	10.00	6.00	1.00	1.00	0.00	0.00	13.00	30.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	RODS (MG/L)	COB (MG/L)	USS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	U. ACIDUS (MG/L)	RODS-S (MG/L)	COB-S (MG/L)	FLUM (L/MTN)
7/ 1/83	695	21.00	7.10	*****	*****	*****	*****	*****	*****	*****	*****	*****	100.00
7/ 2/83	696	21.00	7.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	100.00
7/ 3/83	697	21.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	99.00
7/ 4/83	698	21.00	7.10	*****	*****	*****	*****	*****	*****	*****	*****	*****	100.00
7/ 5/83	699	22.00	7.10	*****	330.00	103.00	129.00	199.00	*****	*****	*****	0.00	100.00
7/ 6/83	700	21.00	7.00	*****	709.00	439.00	539.00	205.00	*****	*****	*****	61.00	100.00
7/ 7/83	701	21.00	6.60	*****	*****	291.00	424.00	211.00	*****	*****	*****	58.00	98.00
7/ 8/83	702	21.00	*****	*****	368.00	89.00	117.00	208.00	*****	*****	*****	55.00	99.00
7/ 9/83	703	20.00	6.80	*****	*****	*****	*****	*****	*****	*****	*****	*****	100.00
7/10/83	704	21.00	6.80	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
7/11/83	705	20.00	6.60	*****	*****	46.00	115.00	208.00	*****	*****	*****	83.00	100.00
7/12/83	706	21.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	99.00
7/13/83	707	21.00	*****	250.00	*****	*****	*****	*****	*****	*****	*****	*****	98.00
7/14/83	708	20.00	*****	*****	299.00	135.00	164.00	190.00	*****	*****	*****	74.00	98.00
7/15/83	709	21.00	*****	167.00	219.00	88.00	109.00	178.00	*****	*****	*****	67.00	98.00
7/16/83	710	21.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	98.00
7/17/83	711	21.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	98.00
7/18/83	712	21.00	*****	147.00	193.00	82.00	99.00	188.00	*****	*****	*****	61.00	98.00
7/19/83	713	*****	*****	177.00	*****	*****	*****	*****	*****	*****	*****	*****	*****
7/20/83	714	21.00	6.60	*****	211.00	99.00	133.00	*****	*****	*****	*****	47.00	96.00
7/21/83	715	21.00	6.20	*****	324.00	160.00	214.00	190.00	*****	*****	*****	51.00	97.00
7/22/83	716	21.00	6.10	*****	188.00	70.00	85.00	186.00	*****	*****	*****	*****	98.00
7/23/83	717	22.00	6.20	*****	*****	*****	*****	*****	*****	*****	*****	*****	98.00
7/24/83	718	22.00	6.40	*****	*****	*****	*****	*****	*****	*****	*****	*****	98.00
7/25/83	719	22.00	6.60	*****	232.00	111.00	127.00	192.00	*****	*****	*****	45.00	103.00
7/26/83	720	22.00	7.00	*****	255.00	68.00	83.00	188.00	*****	*****	*****	89.00	100.00
7/27/83	721	22.00	7.23	*****	204.00	82.00	101.00	190.00	*****	*****	*****	53.00	101.00
7/28/83	722	22.00	7.50	*****	486.00	259.00	307.00	192.00	*****	*****	*****	50.00	90.00
7/29/83	723	22.00	7.50	*****	339.00	193.00	246.00	181.00	*****	*****	*****	65.00	99.00
7/30/83	724	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	99.00
7/31/83	725	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	100.00

SUMMARY:

HIGH	22.00	7.50	*****	250.00	*****	439.00	539.00	211.00	0.00	0.00	0.00	109.00	103.00
LOW	20.00	6.10	*****	147.00	188.00	46.00	83.00	178.00	0.00	0.00	0.00	45.00	90.00
AVERAGE	21.16	6.81	*****	185.25	349.44	144.69	187.00	193.73	0.00	0.00	0.00	64.53	98.86
STD. DEV.	0.61	0.41	*****	44.93	227.28	104.59	132.07	10.15	0.00	0.00	0.00	17.70	2.23
NO. OF POINTS	28.00	19.00	*****	4.00	16.00	16.00	16.00	15.00	0.00	0.00	0.00	15.00	29.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	BOD5 (MG/L)	COD (MG/L)	USS (MG/L)	ISS (MG/L)	ALK (MG/L)	NRA (MG/L)	O ₂ ACTUOS (MG/L)	BOD5-S (MG/L)	COD-S (MG/L)	FLOW (L/MIN)
8/ 1/83	726	22.00	7.20	235.00	546.00	333.00	423.00	189.00	*****	*****	*****	61.00	99.00
8/ 2/83	727	*****	6.40	137.00	*****	*****	*****	*****	*****	*****	*****	*****	99.00
8/ 3/83	728	22.00	7.00	220.00	406.00	240.00	305.00	178.00	*****	*****	*****	63.00	105.00
8/ 4/83	729	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	100.00
8/ 5/83	730	22.00	7.60	*****	939.00	597.00	785.00	220.00	*****	*****	*****	64.00	100.00
8/ 6/83	731	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	100.00
8/ 7/83	732	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	100.00
8/ 8/83	733	21.00	7.80	104.00	275.00	*****	*****	*****	*****	*****	*****	82.00	100.00
8/ 9/83	734	22.00	7.10	*****	696.00	335.00	381.00	211.00	*****	*****	*****	62.00	100.00
8/10/83	735	22.00	7.00	290.00	772.00	476.00	546.00	210.00	*****	*****	*****	131.00	100.00
8/16/83	741	22.00	7.00	*****	259.00	*****	*****	223.00	*****	*****	*****	58.00	100.00
8/17/83	742	22.00	7.10	*****	684.00	385.00	482.00	217.00	*****	*****	*****	96.00	101.00
8/18/83	743	*****	7.43	233.00	428.00	239.00	294.00	206.00	*****	*****	*****	50.00	100.00
8/19/83	744	22.00	6.80	*****	*****	144.00	185.00	260.00	*****	*****	*****	124.00	100.00
8/20/83	745	22.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	100.00
8/21/83	746	22.00	*****	*****	*****	935.00	*****	*****	*****	*****	*****	*****	102.00
8/22/83	747	22.00	7.60	*****	*****	869.00	*****	236.00	*****	*****	*****	183.00	101.00
8/23/83	748	22.00	7.00	*****	*****	719.00	623.00	230.00	*****	*****	*****	111.00	100.00
8/24/83	749	*****	7.20	*****	*****	562.00	942.00	233.00	*****	*****	*****	76.00	101.00
8/25/83	750	*****	*****	*****	691.00	*****	458.00	*****	*****	*****	*****	69.00	100.00
8/26/83	751	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	100.00
8/27/83	752	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	316.00
8/28/83	753	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	276.00
8/29/83	754	*****	*****	*****	*****	497.00	615.00	*****	*****	*****	*****	*****	100.00
8/30/83	755	*****	*****	*****	282.00	143.00	166.00	*****	*****	*****	*****	82.00	298.00
8/31/83	756	*****	*****	*****	254.00	98.00	878.00	*****	*****	*****	*****	51.00	104.00

SUMMARY:

HIGH	22.00	7.80	290.00	*****	935.00	*****	*****	260.00	0.00	0.00	0.00	183.00	316.00
LOW	21.00	6.40	104.00	254.00	98.00	166.00	178.00	0.00	0.00	0.00	0.00	50.00	99.00
AVERAGE	21.92	7.15	203.17	904.35	442.63	576.25	217.69	0.00	0.00	0.00	0.00	84.94	123.15
STD. DEV.	0.28	0.35	69.19	799.68	252.25	296.84	20.79	0.00	0.00	0.00	0.00	34.95	64.17
NO. OF POINTS	13.00	15.00	6.00	17.00	16.00	16.00	13.00	0.00	0.00	0.00	0.00	17.00	26.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	ROD'S (MG/L)	COD (MG/L)	USS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	U. ACYIDS (MG/L)	ROD'S-S (MG/L)	COD-S (MG/L)	FLOW (L/MIN)
9/ 1/83	757	23.00	*****	*****	*****	98.00	878.00	*****	*****	*****	*****	*****	105.00
9/ 2/83	758	*****	*****	330.00	*****	*****	*****	*****	*****	*****	*****	*****	107.00
9/ 3/83	759	23.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	105.00
9/ 4/83	760	23.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	106.00
9/ 5/83	761	23.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
9/ 6/83	762	23.00	7.20	78.00	512.00	6.00	34.00	215.00	*****	*****	*****	53.00	104.00
9/ 7/83	763	23.00	7.10	105.00	196.00	67.00	81.00	203.00	*****	*****	*****	86.00	100.00
9/ 8/83	764	23.00	7.30	*****	221.00	74.00	86.00	199.00	*****	*****	*****	90.00	100.00
9/ 9/83	765	23.00	7.20	*****	437.00	54.00	65.00	203.00	*****	*****	*****	340.00	*****
9/10/83	766	23.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
9/11/83	767	23.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
9/12/83	768	23.00	7.10	*****	528.00	74.00	103.00	*****	*****	*****	*****	411.00	101.00
9/13/83	769	23.00	6.80	*****	586.00	125.00	162.00	*****	*****	*****	*****	395.00	*****
9/14/83	770	23.00	6.80	*****	*****	46.00	*****	*****	*****	*****	*****	393.00	162.00
9/15/83	771	23.00	7.10	*****	175.00	44.00	53.00	*****	*****	*****	*****	82.00	45.00
9/16/83	772	23.00	7.00	139.00	202.00	75.00	92.00	*****	*****	*****	*****	94.00	206.00
9/17/83	773	24.00	7.10	*****	216.00	90.00	106.00	*****	*****	*****	*****	80.00	380.00
9/18/83	774	24.00	6.60	*****	228.00	81.00	96.00	*****	*****	*****	*****	83.00	368.00
9/19/83	775	24.00	6.80	99.00	177.00	80.00	91.00	*****	*****	*****	*****	69.00	150.00
9/20/83	776	24.00	7.00	157.00	185.00	90.00	109.00	*****	*****	*****	*****	82.00	270.00
9/21/83	777	24.00	6.20	86.00	324.00	160.00	214.00	190.00	*****	*****	*****	109.00	102.00
9/22/83	778	22.00	7.40	96.00	196.00	56.00	70.00	*****	*****	*****	*****	74.00	*****
9/23/83	779	*****	*****	183.00	*****	*****	*****	*****	*****	*****	*****	*****	*****
9/27/83	783	22.00	7.20	*****	483.00	190.00	270.00	*****	*****	*****	*****	150.00	21.00
9/28/83	784	22.00	7.00	*****	451.00	185.00	238.00	*****	*****	*****	*****	49.80	23.00
9/29/83	785	21.00	*****	*****	167.00	484.00	621.00	*****	*****	*****	*****	57.50	23.00
9/30/83	786	21.00	*****	160.00	*****	113.00	152.00	*****	*****	*****	*****	*****	35.00

SUMMARY:

HIGH	24.00	7.40	330.00	586.00	484.00	878.00	215.00	0.00	0.00	0.00	0.00	411.00	380.00
LOW	21.00	6.20	78.00	167.00	6.00	34.00	190.00	0.00	0.00	0.00	0.00	49.80	21.00
AVERAGE	22.92	6.99	143.30	309.65	109.60	185.32	202.00	0.00	0.00	0.00	0.00	149.91	131.65
STD. DEV.	0.81	0.29	74.63	149.69	99.55	212.84	9.00	0.00	0.00	0.00	0.00	131.68	103.89
NO. OF POINTS	25.00	17.00	10.00	17.00	20.00	19.00	5.00	0.00	0.00	0.00	0.00	18.00	20.00

89/90

APPENDIX B: CHARACTERISTICS OF EFFLUENT STREAMS

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	BOD5 (MG/L)	COD (MG/L)	VSS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	U-ACIDS (MG/L)	BOD5-S (MG/L)	COD-S (MG/L)	GAS (FT-3/10)	METHANE (% - V/V)
10/ 1/82	422	21.00	6.60	28.00	71.00	9.00	9.00	207.00	*****	139.00	*****	48.00	32.00	76.00
10/ 2/82	423	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
10/ 4/82	425	21.00	6.60	22.00	63.00	10.00	10.00	208.00	*****	110.00	*****	50.00	35.40	72.00
10/ 5/82	426	21.00	6.60	34.00	*****	22.00	23.00	222.00	*****	69.00	*****	*****	38.00	71.00
10/ 6/82	427	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	40.00	70.00
10/ 7/82	428	21.00	6.70	25.00	63.00	6.00	6.00	211.00	*****	96.00	*****	44.00	52.00	69.00
10/ 8/82	429	21.00	6.60	27.00	57.00	7.00	7.00	212.00	*****	89.00	*****	43.00	35.00	74.00
10/ 9/82	430	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	34.00	75.00
10/10/82	431	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	45.00	76.00
10/11/82	432	21.00	6.60	16.00	68.00	7.00	7.00	214.00	*****	94.00	*****	44.00	39.00	75.00
10/12/82	433	21.00	6.60	36.00	91.00	15.00	17.00	224.00	*****	99.00	*****	55.00	33.00	77.00
10/13/82	434	21.00	6.80	32.00	84.00	12.00	14.00	217.00	*****	102.00	*****	55.00	33.00	75.00
10/14/82	435	20.00	6.60	25.00	44.00	9.00	9.00	184.00	*****	91.00	*****	33.00	21.00	76.00
10/15/82	436	20.00	6.70	22.00	40.00	7.00	7.00	211.00	*****	84.00	*****	25.00	17.00	74.00
10/16/82	437	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	16.00	72.00
10/17/82	438	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	9.10	72.00
10/18/82	439	20.00	6.60	25.00	55.00	11.00	11.00	225.00	*****	89.00	*****	33.00	13.70	71.00
10/19/82	440	20.00	6.70	18.00	42.00	9.00	5.00	203.00	*****	110.00	*****	28.00	9.20	71.00
10/20/82	441	20.00	6.70	25.00	48.00	7.00	7.00	205.00	*****	89.00	*****	30.00	12.60	70.40
10/21/82	442	*****	*****	26.00	*****	*****	*****	*****	*****	*****	*****	*****	4.40	46.00
10/22/82	443	20.00	6.70	23.00	32.00	5.00	5.00	200.00	*****	75.00	*****	20.00	17.00	71.40
10/23/82	444	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	21.00	75.00
10/24/82	445	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	20.00	74.00
10/25/82	446	19.00	6.70	20.00	76.00	7.00	7.00	214.00	10.00	99.00	*****	62.00	16.50	71.60
10/26/82	447	19.00	6.60	20.00	69.00	3.00	3.00	210.00	*****	77.00	*****	48.00	10.40	74.00
10/27/82	448	19.00	6.70	22.00	83.00	10.00	10.00	202.00	*****	91.00	*****	61.00	11.50	70.00
10/28/82	449	19.00	6.70	*****	64.00	5.00	5.00	199.00	*****	85.00	*****	44.00	21.00	77.00
10/29/82	450	19.00	6.70	*****	90.00	17.00	17.00	219.00	*****	101.00	*****	60.00	22.00	75.00
10/30/82	451	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	22.00	75.00
10/31/82	452	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	14.80	74.00
SUMMARY														
HIGH		21.00	6.80	36.00	91.00	22.00	23.00	225.00	0.00	139.00	0.00	62.00	52.00	78.00
LOW		19.00	6.60	16.00	32.00	3.00	3.00	184.00	0.00	69.00	0.00	20.00	4.40	46.00
AVERAGE		20.16	6.66	24.63	63.33	9.37	9.42	209.84	0.00	94.16	0.00	43.50	24.12	72.58
STD. DEV.		0.83	0.06	5.18	17.60	4.59	5.08	9.95	0.00	15.37	0.00	12.85	12.11	5.56
NO. OF POINTS		19.00	19.00	19.00	18.00	19.00	19.00	19.00	1.00	19.00	0.00	18.00	30.00	30.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	FH	RODS (MG/L)	COD (MG/L)	VSS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	V. ACIDS (MG/L)	RODS-S (MG/L)	COD-S (MG/L)	GAS (FT-3/B)	METHANE (Z - V/V)
11/ 1/82	453	*****	*****	34.00	*****	*****	*****	*****	*****	*****	*****	*****	11.80	71.50
11/ 3/82	454	19.00	6.70	29.00	67.00	6.00	6.00	226.00	*****	92.00	*****	45.00	19.00	75.00
11/ 4/82	455	19.00	6.60	37.00	79.00	17.00	18.00	196.00	*****	81.00	*****	42.00	14.00	*****
11/ 4/82	456	19.00	6.60	26.00	58.00	10.00	10.00	179.00	10.00	72.00	*****	34.00	43.00	74.00
11/ 5/82	457	18.00	6.70	30.00	71.00	17.00	20.00	191.00	*****	101.00	*****	44.00	18.30	69.70
11/ 7/82	459	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.10	66.00
11/ 8/82	460	18.00	6.70	35.00	77.00	11.00	11.00	221.00	*****	107.00	*****	53.00	3.80	64.00
11/ 9/82	461	18.00	6.60	36.00	69.00	10.00	11.00	*****	*****	96.00	*****	42.00	3.40	71.00
11/10/82	462	17.00	6.70	31.00	66.00	10.00	14.00	205.00	*****	*****	*****	37.00	4.20	64.00
11/11/82	463	18.00	6.70	*****	63.00	7.00	7.00	218.00	*****	190.00	*****	42.00	0.90	66.00
11/12/82	464	18.00	6.70	37.00	60.00	12.00	12.00	208.00	*****	158.00	*****	33.00	*****	68.00
11/13/82	465	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	7.50	70.40
11/14/82	466	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	10.00	71.00
11/15/82	467	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
11/16/82	468	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
11/17/82	469	17.00	*****	33.00	73.00	13.00	13.00	215.00	*****	*****	*****	44.00	*****	*****
11/18/82	470	17.00	6.90	27.00	63.00	12.00	12.00	203.00	*****	103.00	*****	49.00	*****	*****
11/19/82	471	17.00	6.60	34.00	67.00	8.00	10.00	194.00	*****	116.00	*****	47.00	*****	*****
11/22/82	474	17.00	6.60	31.00	70.00	7.00	11.00	214.00	*****	99.00	*****	45.00	22.00	57.00
11/23/82	475	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	63.00	51.00
11/24/82	476	*****	*****	23.00	*****	*****	*****	*****	*****	*****	*****	*****	4.50	47.00
11/27/82	479	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	11.50	48.00
11/28/82	480	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	2.75	65.00
11/29/82	481	16.00	6.60	22.00	62.00	6.00	8.00	189.00	*****	118.00	*****	44.00	2.20	65.00
11/30/82	482	16.00	6.60	17.00	36.00	5.00	5.00	*****	*****	*****	*****	26.00	2.50	68.00

SUMMARY

HIGH	19.00	6.90	38.00	79.00	17.00	20.00	226.00	0.00	190.00	53.00	63.00	75.00
LOW	16.00	6.60	17.00	36.00	5.00	5.00	179.00	0.00	72.00	26.00	0.10	47.00
AVERAGE	17.60	6.66	30.22	65.40	10.07	11.20	204.54	0.00	111.08	41.80	12.87	64.48
STD. DEV.	0.99	0.08	5.99	10.07	3.73	4.07	14.10	0.00	32.83	6.82	15.92	8.22
NO. OF POINTS	15.00	14.00	18.00	15.00	15.00	15.00	13.00	1.00	12.00	15.00	19.00	20.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	RODS (MG/L)	COD (MG/L)	USS (MG/L)	TSS (MG/L)	AI K (MG/L)	NH4 (MG/L)	V. ACTINS (MG/L)	MODS-S (MG/L)	COD-S (MG/L)	GAS (FT-3/D)	METHANE (% - V/V)
12/ 1/82	483	16.00	6.60	30.00	54.00	5.00	6.00	148.00	190.00	105.00	103.00	42.00	13.10	*****
12/ 2/82	484	16.00	6.60	12.00	43.00	4.00	6.00	148.00	*****	*****	*****	39.00	30.00	55.50
12/ 3/82	485	*****	*****	17.00	*****	*****	*****	*****	*****	105.00	*****	*****	*****	*****
12/ 6/82	488	16.00	6.60	20.00	41.00	5.00	6.00	182.00	*****	96.00	*****	35.00	15.00	45.00
12/ 7/82	489	16.00	6.70	20.00	*****	0.00	0.00	192.00	4.00	102.00	*****	*****	22.00	48.00
12/ 8/82	490	16.00	*****	20.00	42.00	4.00	4.00	*****	*****	*****	*****	30.00	1.50	51.20
12/ 9/82	491	16.00	6.70	22.00	52.00	4.00	4.00	194.00	10.00	*****	*****	30.00	0.30	*****
12/10/82	492	16.00	6.60	20.00	53.00	6.00	6.00	203.00	*****	132.00	*****	47.00	0.15	50.00
12/11/82	493	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.54	54.00
12/12/82	494	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.00	*****
12/13/82	495	*****	*****	15.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	57.00
12/14/82	496	14.00	6.70	16.00	38.00	1.00	2.00	190.00	7.00	132.00	*****	26.00	1.70	58.00
12/15/82	497	15.00	6.70	21.00	51.00	5.00	6.00	166.00	*****	118.00	*****	33.00	0.17	59.00
12/16/82	498	14.00	6.60	23.00	29.00	5.00	6.00	190.00	10.00	116.00	*****	14.00	0.21	61.00
12/17/82	499	15.00	6.60	14.00	29.00	2.00	2.00	171.00	*****	171.00	*****	14.00	0.60	61.00
12/18/82	500	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	1.70	49.00
12/19/82	501	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	2.40	42.00
12/20/82	502	14.00	6.80	19.00	37.00	4.00	4.00	190.00	*****	132.00	*****	24.00	4.40	57.00
12/21/82	503	14.00	6.80	24.00	48.00	7.00	7.00	195.00	*****	119.00	*****	26.00	1.20	58.00
12/22/82	504	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	61.00
12/23/82	505	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.60	56.00
12/24/82	506	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	1.50	60.00
12/25/82	507	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	17.00	64.00
12/26/82	508	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	2.30	52.30
12/27/82	509	*****	*****	28.00	63.00	15.00	20.00	199.00	*****	*****	*****	41.00	2.10	67.20
12/28/82	510	15.00	6.60	14.00	73.00	13.00	18.00	209.00	*****	*****	*****	41.00	5.90	69.30
12/29/82	511	*****	*****	16.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	64.00
12/30/82	512	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	3.90	46.00
12/31/82	513	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.18	45.00

SUMMARY

HIGH	16.00	6.80	30.00	73.00	15.00	20.00	209.00	190.00	171.00	0.00	47.00	30.00	69.30
LOW	14.00	6.60	12.00	29.00	1.00	2.00	148.00	4.00	96.00	0.00	14.00	0.15	42.00
AVERAGE	15.21	6.66	19.50	46.64	5.71	6.93	186.85	44.20	122.30	0.00	31.57	5.35	55.62
STD. DEV.	0.89	0.08	4.81	12.29	3.83	5.36	16.56	81.54	21.41	0.00	10.14	8.02	7.26
NO. OF POINTS	14.00	13.00	18.00	14.00	14.00	14.00	13.00	5.00	10.00	1.00	14.00	24.00	25.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	FH	RODS (MG/L)	COD (MG/L)	USS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	V. ACIDUS (MG/L)	RODS-S (MG/L)	COD-S (MG/L)	GAS (FT-3/L)	METHANE (Z - U/V)
1/ 1/83	514	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	2.00	*****
1/ 2/83	515	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.30	53.30
1/ 3/83	516	*****	*****	33.00	*****	*****	*****	*****	*****	*****	*****	*****	0.96	55.00
1/ 4/83	517	14.00	6.70	27.00	*****	8.00	8.00	231.00	8.00	118.00	*****	*****	1.80	57.00
1/ 5/83	518	14.00	6.80	41.00	68.00	10.00	10.00	232.00	*****	111.00	*****	53.00	1.40	55.50
1/ 6/83	519	14.00	7.10	30.00	63.00	8.00	8.00	209.00	*****	141.00	*****	38.00	1.70	57.00
1/ 7/83	520	14.00	6.70	23.00	68.00	14.00	12.00	212.00	*****	110.00	*****	45.00	4.80	55.00
1/ 8/83	521	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.40	49.00
1/ 9/83	522	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	7.30	49.00
1/10/83	523	*****	*****	32.00	*****	*****	*****	*****	*****	*****	*****	*****	9.40	50.00
1/11/83	524	14.00	6.70	36.00	70.00	9.00	10.00	179.00	*****	120.00	*****	40.00	3.70	50.00
1/12/83	525	12.00	6.70	26.00	61.00	8.00	9.00	210.00	*****	115.00	*****	39.00	0.50	43.00
1/13/83	526	13.00	6.80	31.00	57.00	8.00	10.00	216.00	*****	245.00	*****	43.00	2.50	39.00
1/14/83	527	*****	*****	38.30	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
1/15/83	528	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.30	*****
1/16/83	529	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.00	*****
1/17/83	530	13.00	6.80	25.00	73.00	14.00	14.00	209.00	*****	*****	*****	55.00	0.85	*****
1/18/83	531	14.00	6.60	26.00	64.00	10.00	10.00	211.00	*****	*****	*****	46.00	1.20	37.00
1/19/83	532	*****	*****	26.00	*****	*****	*****	*****	*****	*****	*****	*****	0.40	58.70
1/20/83	533	13.00	6.90	35.00	88.00	12.00	12.00	210.00	*****	*****	*****	59.00	1.70	37.00
1/21/83	534	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.00	33.00
1/22/83	535	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.50	34.00
1/23/83	536	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.80	35.00
1/24/83	537	13.00	6.80	29.00	77.00	11.00	11.00	211.00	*****	*****	*****	49.00	0.20	32.00
1/25/83	538	13.00	6.80	28.00	74.00	15.00	15.00	214.00	*****	277.00	*****	62.00	0.00	32.00
1/26/83	539	*****	*****	31.00	*****	*****	*****	*****	*****	*****	*****	*****	0.20	32.00
1/27/83	540	13.00	6.80	35.00	84.00	17.00	18.00	207.00	*****	*****	*****	51.00	0.00	31.00
1/28/83	541	13.00	6.80	31.00	73.00	14.00	16.00	212.00	*****	*****	*****	46.00	0.00	30.00
1/29/83	542	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.10	28.00
1/30/83	543	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.20	18.00
1/31/83	544	13.00	6.80	*****	87.00	15.00	15.00	212.00	*****	36.00	*****	63.00	0.00	30.00

SUMMARY

HIGH	14.00	7.10	41.00	88.00	17.00	18.00	232.00	0.00	277.00	0.00	63.00	9.40	58.70
LOW	12.00	6.60	25.00	57.00	8.00	8.00	179.00	0.00	36.00	0.00	38.00	0.10	18.00
AVERAGE	13.33	6.79	30.96	71.93	11.53	11.87	211.67	0.00	141.44	0.00	49.21	1.80	41.56
STD. DEV.	0.62	0.11	4.50	9.54	3.09	3.07	11.71	0.00	74.03	0.00	8.29	2.35	11.55
NO. OF POINTS	15.00	15.00	19.00	14.00	15.00	15.00	15.00	1.00	9.00	0.00	14.00	24.00	26.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	BOD5 (MG/L)	COD (MG/L)	VSS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	V.ACTIS (MG/L)	BOD5-S (MG/L)	COD-S (MG/L)	GAS (FT-3/H)	METHANE (% - V/V)
2/ 1/83	545	13.00	6.80	7.20	84.00	12.00	14.00	211.00	*****	*****	*****	80.00	*****	29.00
2/ 2/83	546	14.00	6.60	27.00	85.00	15.00	15.00	200.00	*****	*****	*****	48.00	0.42	29.00
2/ 3/83	547	14.00	6.70	19.00	60.00	11.00	17.00	175.00	6.00	*****	*****	44.00	0.90	28.00
2/ 4/83	548	13.00	6.80	20.00	57.00	7.00	7.00	197.00	*****	*****	*****	35.00	0.42	24.00
2/ 5/83	549	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.20	24.00
2/ 6/83	550	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	2.60	23.00
2/ 7/83	551	12.00	6.80	23.00	62.00	10.00	11.00	184.00	*****	*****	*****	45.00	0.16	20.00
2/ 8/83	552	*****	*****	25.00	*****	*****	*****	*****	*****	*****	*****	*****	0.10	19.00
2/ 9/83	553	13.00	6.80	35.00	64.00	6.00	8.00	195.00	*****	*****	*****	41.00	0.80	*****
2/10/83	554	13.00	6.80	19.00	*****	8.00	8.00	*****	*****	*****	*****	*****	0.21	15.00
2/11/83	555	12.00	6.70	20.00	66.00	10.00	15.00	177.00	*****	*****	*****	43.00	0.20	15.00
2/13/83	557	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.00	11.70
2/14/83	558	13.00	6.70	21.00	52.00	*****	*****	189.00	*****	*****	*****	34.00	0.30	10.70
2/15/83	559	*****	*****	30.00	*****	*****	*****	*****	*****	*****	*****	*****	0.00	9.60
2/16/83	560	13.00	6.60	28.00	66.00	9.00	11.00	195.00	*****	*****	*****	44.00	0.00	8.50
2/17/83	561	14.00	6.70	26.00	*****	10.00	10.00	*****	*****	*****	*****	*****	0.00	8.50
2/18/83	562	*****	*****	25.00	*****	*****	*****	*****	*****	*****	*****	*****	0.25	*****
2/19/83	563	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.50	7.50
2/20/83	564	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.00	6.40
2/21/83	565	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.21	*****
2/22/83	566	*****	*****	32.00	*****	*****	*****	*****	*****	*****	*****	*****	0.42	5.30
2/23/83	567	13.00	6.80	25.00	59.00	12.00	13.00	173.00	14.00	*****	*****	42.00	0.21	5.30
2/24/83	568	13.00	7.10	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.25	*****
2/25/83	569	13.00	6.80	*****	*****	9.00	9.00	190.00	*****	*****	*****	*****	0.85	5.30
2/26/83	570	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	2.00	5.30
2/27/83	571	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.00	4.30
2/28/83	572	13.00	6.80	27.00	73.00	11.00	11.00	203.00	*****	*****	*****	43.00	0.85	*****

SUMMARY

HIGH	14.00	7.10	35.00	85.00	15.00	17.00	211.00	14.00	0.00	0.00	80.00	2.60	29.00
LOW	12.00	6.60	7.20	52.00	6.00	7.00	173.00	6.00	0.00	0.00	34.00	0.10	4.30
AVERAGE	13.07	6.77	24.07	66.18	10.00	11.46	190.75	10.00	0.00	0.00	45.36	0.59	14.29
STD. DEV.	0.59	0.12	6.31	10.56	2.35	3.13	11.76	5.66	0.00	0.00	12.20	0.64	8.68
NO. OF POINTS	15.00	15.00	17.00	11.00	13.00	13.00	12.00	2.00	0.00	0.00	11.00	20.00	22.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	RODS (MG/L)	COD (MG/L)	USS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	U-ACIDS (MG/L)	RODS-S (MG/L)	COD-S (MG/L)	GAS (FT-3/H)	METHANE (% - U/V)
3/ 1/83	573	*****	*****	25.00	*****	*****	*****	*****	*****	*****	*****	*****	0.21	4.30
3/ 2/83	574	13.00	*****	27.00	59.00	9.00	9.00	194.00	*****	*****	*****	38.00	0.20	4.30
3/ 3/83	575	13.00	6.70	51.00	*****	10.00	12.00	200.00	12.00	*****	*****	*****	0.20	4.30
3/ 4/83	576	14.00	*****	*****	75.00	6.00	6.00	197.00	*****	*****	*****	46.00	0.11	4.30
3/ 5/83	577	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.20	4.30
3/ 7/83	579	14.00	6.70	41.00	93.00	6.00	6.00	200.00	*****	*****	*****	74.00	0.11	4.30
3/ 8/83	580	*****	*****	48.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	4.30
3/ 9/83	581	14.00	6.70	40.00	74.00	14.00	14.00	189.00	*****	*****	*****	62.00	0.24	4.30
3/10/83	582	14.00	6.70	32.00	*****	*****	*****	*****	10.00	*****	*****	*****	0.32	5.30
3/11/83	583	*****	*****	41.00	*****	*****	*****	*****	*****	*****	*****	*****	0.11	*****
3/12/83	584	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.32	4.30
3/14/83	586	14.00	*****	50.00	*****	11.00	11.00	188.00	*****	*****	*****	*****	0.11	4.30
3/15/83	587	14.00	*****	48.00	*****	9.00	9.00	200.00	*****	*****	*****	*****	0.00	*****
3/16/83	588	*****	*****	42.00	*****	*****	*****	*****	*****	*****	*****	*****	0.00	*****
3/17/83	589	18.00	6.50	29.00	98.00	9.00	9.00	*****	10.00	10.00	*****	70.00	0.00	4.60
3/18/83	590	18.00	6.50	46.00	92.00	12.00	15.00	194.00	*****	*****	*****	74.00	0.32	*****
3/20/83	592	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	45.00	8.50
3/21/83	593	18.00	6.40	45.00	112.00	12.00	12.00	194.00	*****	*****	*****	87.00	0.60	*****
3/22/83	594	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	1.40	9.00
3/23/83	595	18.00	*****	53.00	131.00	13.00	13.00	191.00	*****	*****	*****	86.00	0.56	*****
3/24/83	596	19.00	6.50	47.00	*****	15.00	15.00	*****	10.00	*****	*****	*****	0.00	9.40
3/25/83	597	18.00	*****	*****	111.00	*****	*****	*****	*****	*****	*****	80.00	1.40	9.60
3/26/83	598	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.10	*****
3/27/83	599	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.00	9.60
3/28/83	600	18.00	6.60	44.00	85.00	12.00	13.00	164.00	*****	*****	*****	43.00	0.00	10.00
3/29/83	601	*****	*****	60.00	*****	*****	*****	*****	*****	*****	*****	*****	0.00	9.60
3/30/83	602	18.00	*****	37.00	82.00	11.00	12.00	*****	*****	*****	*****	61.00	43.00	8.50
3/31/83	603	*****	*****	41.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
SUMMARY														
HIGH		19.00	6.70	60.00	131.00	15.00	15.00	200.00	12.00	0.00	0.00	87.00	45.00	10.00
LOW		13.00	6.40	25.00	59.00	6.00	6.00	164.00	10.00	0.00	0.00	38.00	0.10	4.30
AVERAGE		15.94	6.59	42.35	92.00	10.64	11.14	190.17	10.50	0.00	0.00	65.55	4.97	6.36
STD. DEV.		2.29	0.12	8.97	20.42	2.68	2.96	11.44	1.00	0.00	0.00	17.13	13.76	2.48
NO. OF POINTS		16.00	9.00	20.00	11.00	14.00	14.00	12.00	4.00	1.00	0.00	11.00	19.00	20.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	RODS (MG/L)	COD (MG/L)	VSS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	V. ACIDUS (MG/L)	RODS-S (MG/L)	COD-S (MG/L)	GAS (FT-3/R)	METHANE (Z - V/V)
4/ 1/83	604	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	37.00	8.50
4/ 2/83	605	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.60	10.60
4/ 3/83	606	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.60	9.60
4/ 4/83	607	18.00	6.60	54.00	109.00	16.00	18.00	199.00	*****	*****	*****	95.00	0.21	9.60
4/ 5/83	608	19.00	6.50	57.00	*****	*****	*****	*****	*****	*****	*****	*****	0.00	*****
4/ 6/83	609	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	40.30	11.00
4/ 7/83	610	22.00	6.30	59.00	*****	*****	*****	*****	*****	*****	*****	*****	38.00	17.00
4/ 8/83	611	22.00	6.30	*****	13.00	*****	16.00	*****	*****	*****	*****	*****	53.00	23.00
4/ 9/83	612	*****	*****	*****	99.00	*****	*****	*****	*****	*****	*****	79.00	50.00	27.70
4/10/83	613	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	32.40	31.00
4/11/83	614	23.00	6.40	45.00	*****	*****	*****	*****	*****	*****	*****	*****	46.00	33.00
4/12/83	615	*****	*****	45.00	74.00	*****	*****	*****	*****	*****	*****	41.00	57.00	34.00
4/13/83	616	*****	*****	37.00	*****	*****	*****	*****	*****	*****	*****	*****	48.00	*****
4/14/83	617	*****	*****	29.00	*****	*****	*****	*****	*****	*****	*****	*****	52.00	39.00
4/15/83	618	*****	*****	29.00	72.00	7.00	11.00	193.00	*****	*****	*****	51.00	45.00	42.00
4/16/83	619	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	36.60	*****
4/17/83	620	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	23.70	*****
4/18/83	621	*****	*****	*****	101.00	17.00	16.00	*****	*****	*****	*****	*****	48.00	*****
4/19/83	622	*****	*****	*****	94.00	7.00	16.00	*****	*****	*****	*****	73.00	43.00	*****
4/20/83	623	*****	*****	35.00	*****	*****	*****	*****	*****	*****	*****	*****	42.00	49.00
4/21/83	624	*****	*****	32.00	69.00	6.00	7.00	201.00	10.00	*****	*****	56.00	41.00	48.00
4/22/83	625	*****	6.65	44.00	*****	*****	*****	*****	*****	*****	*****	*****	33.40	48.00
4/23/83	626	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	44.50	47.00
4/24/83	627	*****	7.00	56.00	112.00	19.00	22.00	199.00	*****	*****	*****	62.00	90.90	50.00
4/25/83	628	*****	*****	55.00	*****	*****	*****	*****	8.00	*****	*****	*****	33.00	52.00
4/26/83	629	*****	*****	*****	86.00	8.00	12.00	208.00	*****	*****	*****	74.00	37.00	52.00
4/27/83	630	*****	7.10	26.00	*****	*****	*****	*****	*****	*****	*****	*****	39.00	52.00
4/28/83	631	*****	*****	13.00	38.00	10.00	5.00	197.00	*****	*****	*****	25.00	45.00	52.30
4/29/83	632	24.00	7.80	*****	*****	*****	*****	*****	*****	*****	*****	*****	45.00	52.30
4/30/83	633	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	45.00	52.30

SUMMARY

HIGH	24.00	7.80	59.00	112.00	19.00	22.00	208.00	10.00	0.00	0.00	0.00	95.00	90.90	52.30
LOW	18.00	6.30	13.00	38.00	6.00	5.00	193.00	8.00	0.00	0.00	0.00	25.00	0.21	8.50
AVERAGE	21.33	6.74	41.07	85.40	11.44	13.67	199.50	9.00	0.00	0.00	0.00	63.10	39.90	34.72
STD. DEV.	2.34	0.49	13.73	22.59	4.93	5.41	4.97	1.41	0.00	0.00	0.00	20.46	17.86	16.70
NO. OF POINTS	6.00	9.00	15.00	10.00	9.00	9.00	6.00	2.00	0.00	0.00	0.00	10.00	29.00	23.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	RODS (MG/L)	COD (MG/L)	USS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	U. ACIDS (MG/L)	RODS-S (MG/L)	COD-S (MG/L)	GAS (FT-3/D)	METHANE (% - V/V)
5/ 1/83	634	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	44.00	52.00
5/ 2/83	635	24.00	7.30	*****	76.00	11.00	11.00	197.00	*****	*****	*****	71.00	44.00	51.00
5/ 3/83	636	*****	*****	35.00	*****	*****	*****	*****	*****	*****	*****	*****	53.00	51.00
5/ 4/83	637	24.00	7.30	33.00	*****	7.00	10.00	187.00	*****	*****	*****	*****	3.90	*****
5/ 5/83	638	24.00	*****	*****	*****	8.00	9.00	*****	10.00	*****	*****	*****	32.00	53.00
5/ 6/83	639	*****	*****	55.00	*****	*****	*****	*****	*****	*****	*****	*****	27.00	*****
5/ 7/83	640	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	50.00	52.00
5/ 8/83	641	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	34.00	52.30
5/ 9/83	642	24.00	7.20	56.00	109.00	14.00	17.00	191.00	12.00	*****	*****	78.00	24.00	*****
5/10/83	643	*****	*****	34.00	*****	*****	*****	*****	*****	*****	*****	*****	9.00	*****
5/11/83	644	*****	*****	45.00	*****	*****	*****	*****	*****	*****	*****	*****	62.80	*****
5/12/83	645	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	74.00	70.00
5/13/83	646	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	42.40	*****
5/14/83	647	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	63.50	*****
5/15/83	648	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	38.00	62.00
5/16/83	649	24.00	7.10	39.00	109.00	19.00	17.00	191.00	*****	*****	*****	71.00	23.00	59.00
5/17/83	650	24.00	7.10	28.00	*****	*****	*****	195.00	8.00	*****	*****	*****	9.70	60.00
5/18/83	651	24.00	7.00	30.00	*****	14.00	14.00	*****	*****	*****	*****	*****	14.90	58.00
5/19/83	652	23.00	*****	46.00	83.00	*****	*****	*****	*****	*****	*****	60.00	11.80	58.80
5/20/83	653	*****	*****	29.00	*****	*****	*****	*****	*****	*****	*****	*****	14.20	56.40
5/21/83	654	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	13.20	57.00
5/22/83	655	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	96.00	53.00
5/23/83	656	24.00	7.00	18.00	45.00	10.00	10.00	175.00	*****	*****	*****	27.00	32.70	53.50
5/24/83	657	23.00	7.10	13.00	*****	*****	*****	*****	6.00	*****	*****	*****	6.20	52.60
5/25/83	658	*****	*****	17.00	*****	*****	*****	*****	*****	*****	*****	*****	28.00	53.00
5/26/83	659	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
5/27/83	660	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	16.00	49.80
5/28/83	661	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	17.50	*****
5/29/83	662	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	7.80	*****
5/31/83	664	*****	7.20	28.00	61.00	12.00	12.00	119.00	*****	*****	*****	33.00	0.00	46.90

SUMMARY

HIGH	24.00	7.30	56.00	109.00	19.00	17.00	197.00	12.00	0.00	0.00	0.00	78.00	96.00	70.00
LOW	23.00	7.00	13.00	45.00	7.00	9.00	119.00	6.00	0.00	0.00	0.00	27.00	3.90	46.90
AVERAGE	23.80	7.14	32.69	80.50	11.88	12.50	179.29	9.00	0.00	0.00	0.00	56.67	31.88	55.07
STD. DEV.	0.42	0.11	13.11	25.66	3.83	3.16	27.53	2.58	0.00	0.00	0.00	21.53	22.85	5.20
NO. OF POINTS	10.00	9.00	16.00	6.00	8.00	8.00	7.00	4.00	0.00	0.00	0.00	6.00	28.00	20.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	RODS (MG/L)	COD (MG/L)	USS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	V-ACIDS (MG/L)	MOOS-S (MG/L)	COD-S (MG/L)	GAS (FT-3/H)	METHANE (% - V/V)
6/ 1/83	665	17.00	7.00	21.00	84.00	11.00	11.00	*****	*****	*****	*****	50.00	12.20	*****
6/ 2/83	666	17.00	7.20	27.00	73.00	*****	*****	202.00	*****	*****	*****	35.00	66.00	40.00
6/ 3/83	667	18.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	17.00	39.00
6/ 4/83	668	18.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	46.00	40.00
6/ 5/83	669	18.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	78.00	39.00
6/ 6/83	670	18.00	*****	6.00	*****	*****	*****	*****	*****	*****	*****	*****	22.00	*****
6/ 7/83	671	18.00	*****	22.00	*****	*****	*****	*****	*****	*****	*****	*****	11.00	*****
6/ 8/83	672	18.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	2.00	*****
6/ 9/83	673	20.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	117.00	41.00
6/10/83	674	24.00	6.90	*****	115.00	*****	34.00	*****	*****	*****	*****	67.00	118.90	40.50
6/11/83	675	24.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	132.00	44.00
6/12/83	676	24.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	22.00	44.00
6/13/83	677	25.00	7.20	25.00	50.00	10.00	10.00	218.00	*****	*****	*****	35.00	17.00	44.00
6/14/83	678	25.00	6.90	28.00	*****	*****	*****	*****	*****	*****	*****	*****	98.00	52.00
6/15/83	679	27.00	*****	29.00	58.00	8.00	10.00	*****	*****	*****	*****	20.00	11.00	53.00
6/16/83	680	26.00	6.60	*****	*****	*****	*****	*****	*****	*****	*****	*****	23.00	53.00
6/17/83	681	26.00	6.70	*****	52.00	8.00	10.00	221.00	*****	*****	*****	34.00	79.00	53.00
6/18/83	682	25.00	6.80	*****	*****	*****	*****	*****	*****	*****	*****	*****	64.00	53.00
6/19/83	683	30.00	6.70	*****	*****	*****	*****	*****	*****	*****	*****	*****	24.00	53.00
6/20/83	684	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	67.00	53.00
6/21/83	685	24.00	6.80	63.00	169.00	*****	*****	*****	*****	*****	*****	*****	52.00	53.00
6/22/83	686	24.00	6.90	57.00	63.00	*****	*****	*****	*****	*****	*****	47.00	86.00	53.00
6/23/83	687	23.00	6.90	*****	93.00	19.00	18.00	*****	*****	*****	*****	71.00	0.90	53.00
6/24/83	688	22.00	6.90	52.00	109.00	20.00	25.00	*****	*****	*****	*****	60.00	0.00	53.00
6/25/83	689	22.00	6.70	*****	*****	*****	*****	*****	*****	*****	*****	*****	54.00	61.00
6/26/83	690	23.00	6.30	*****	*****	*****	*****	*****	*****	*****	*****	*****	92.00	62.00
6/27/83	691	22.00	6.60	57.00	120.00	16.00	18.00	190.00	*****	*****	*****	79.00	113.50	65.00
6/28/83	692	22.00	6.60	46.00	109.00	16.00	17.00	225.00	2.00	*****	*****	73.00	70.00	63.00
6/29/83	693	22.00	6.60	*****	*****	*****	*****	*****	33.00	*****	*****	*****	65.00	63.00
6/30/83	694	21.00	7.10	39.00	87.00	14.00	15.00	222.00	*****	*****	*****	70.00	59.00	63.00
SUMMARY														
HIGH		30.00	7.20	63.00	169.00	20.00	34.00	225.00	33.00	0.00	0.00	79.00	132.00	65.00
LOW		17.00	6.30	6.00	50.00	8.00	10.00	190.00	2.00	0.00	0.00	20.00	0.90	39.00
AVERAGE		22.17	6.81	36.31	90.92	13.56	16.80	213.00	17.50	0.00	0.00	53.23	55.84	51.17
STD. DEV.		3.38	0.23	17.35	33.69	4.53	7.76	13.89	21.92	0.00	0.00	18.44	38.64	8.43
NO. OF POINTS		29.00	19.00	13.00	13.00	9.00	10.00	6.00	2.00	0.00	0.00	13.00	29.00	26.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	BOD5 (MG/L)	COD (MG/L)	VSS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	U. ACIDS (MG/L)	BOD5-S (MG/L)	COD-S (MG/L)	GAS (FT-3/D)	METHANE (% - V/V)
7/ 1/83	695	21.00	6.70	*****	*****	*****	*****	*****	*****	*****	*****	*****	75.00	62.00
7/ 2/83	696	21.00	6.70	*****	*****	*****	*****	*****	*****	*****	*****	*****	89.50	62.00
7/ 3/83	697	21.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	84.00	64.00
7/ 4/83	698	21.00	6.70	*****	*****	*****	*****	*****	*****	*****	*****	*****	99.00	65.00
7/ 5/83	699	21.00	6.70	*****	29.00	12.00	16.00	224.00	*****	*****	*****	4.00	87.00	65.00
7/ 6/83	700	21.00	6.40	*****	93.00	19.00	22.00	217.00	*****	*****	*****	74.00	*****	59.00
7/ 7/83	701	22.00	6.60	34.00	92.00	9.00	9.00	216.00	*****	*****	*****	55.00	132.00	64.00
7/ 8/83	702	21.00	*****	39.00	77.00	8.00	10.00	214.00	*****	*****	*****	46.00	123.00	65.00
7/ 9/83	703	21.00	6.50	*****	*****	*****	*****	*****	*****	*****	*****	*****	140.00	67.00
7/10/83	704	21.00	6.50	*****	*****	*****	*****	*****	*****	*****	*****	*****	143.00	65.00
7/11/83	705	21.00	6.60	47.00	135.00	36.00	92.00	212.00	*****	*****	*****	93.00	119.00	69.00
7/12/83	706	21.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	143.00	69.00
7/13/83	707	21.00	*****	74.00	*****	*****	*****	*****	*****	*****	*****	*****	111.00	71.00
7/14/83	708	21.00	*****	60.00	131.00	34.00	44.00	217.00	*****	*****	*****	65.00	*****	71.00
7/15/83	709	21.00	*****	*****	135.00	31.00	37.00	215.00	*****	*****	*****	89.00	161.00	72.00
7/16/83	710	21.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	192.00	72.00
7/17/83	711	21.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	152.00	73.00
7/18/83	712	21.00	*****	60.00	114.00	27.00	34.00	212.00	*****	*****	*****	60.00	161.00	73.00
7/19/83	713	*****	*****	46.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
7/20/83	714	22.00	6.60	*****	103.00	*****	39.00	*****	*****	*****	*****	79.00	174.00	76.00
7/21/83	715	21.00	6.70	*****	87.00	22.00	24.00	184.00	*****	*****	*****	38.00	130.00	78.00
7/22/83	716	21.00	6.80	*****	77.00	17.00	20.00	210.00	*****	*****	*****	48.00	132.00	76.00
7/23/83	717	22.00	6.80	*****	*****	*****	*****	*****	*****	*****	*****	*****	151.00	75.00
7/24/83	718	22.00	6.80	*****	*****	*****	*****	*****	*****	*****	*****	*****	132.00	75.00
7/25/83	719	22.00	6.80	*****	38.00	19.00	19.00	217.00	*****	*****	*****	11.00	133.00	75.00
7/26/83	720	22.00	6.80	*****	109.00	19.00	22.00	216.00	*****	*****	*****	76.00	120.00	79.00
7/27/83	721	22.00	7.10	*****	103.00	18.00	22.00	210.00	*****	*****	*****	48.00	150.00	75.00
7/28/83	722	22.00	7.30	*****	78.00	24.00	21.00	205.00	*****	*****	*****	41.00	143.00	72.00
7/29/83	723	22.00	7.20	*****	84.00	24.00	25.00	216.00	*****	*****	*****	47.00	144.00	71.60
7/30/83	724	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	136.00	73.00
7/31/83	725	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	161.00	73.00

SUMMARY

HIGH	22.00	7.30	74.00	135.00	36.00	92.00	224.00	0.00	0.00	93.00	192.00	79.00
LOW	21.00	6.40	34.00	29.00	8.00	9.00	184.00	0.00	0.00	4.00	75.00	59.00
AVERAGE	21.32	6.75	54.00	92.81	21.27	28.50	212.33	0.00	0.00	54.63	132.77	70.22
STD. DEV.	0.48	0.23	14.80	30.38	8.36	19.57	8.94	0.00	0.00	24.99	27.79	5.25
NO. OF POINTS	28.00	19.00	8.00	16.00	15.00	16.00	15.00	0.00	0.00	16.00	28.00	30.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	ROD5 (MG/L)	COB (MG/L)	USS (MG/L)	TSS (MG/L)	ALK (MG/L)	NH4 (MG/L)	V.ACTIDS (MG/L)	ROD5-S (MG/L)	COB-S (MG/L)	GAS (FT-3/10)	METHANE (% - V/V)
8/ 1/83	726	22.00	7.20	45.00	120.00	39.00	44.00	215.00	*****	*****	*****	48.00	162.00	74.00
8/ 2/83	727	*****	*****	51.00	*****	*****	*****	*****	*****	*****	*****	*****	156.00	73.00
8/ 3/83	728	22.00	7.10	52.00	111.00	27.00	34.00	206.00	*****	*****	*****	56.00	179.00	73.00
8/ 4/83	729	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	201.00	74.00
8/ 5/83	730	22.00	7.20	*****	132.00	34.00	39.00	219.00	*****	*****	*****	54.00	198.00	73.00
8/ 6/83	731	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	243.00	75.00
8/ 7/83	732	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	239.00	74.00
8/ 8/83	733	22.00	6.80	*****	278.00	*****	*****	*****	*****	*****	*****	99.00	190.00	77.00
8/ 9/83	734	22.00	6.80	*****	267.00	107.00	132.00	241.00	*****	*****	*****	91.00	151.00	75.00
8/10/83	735	22.00	7.20	145.00	334.00	145.30	182.00	233.00	*****	*****	*****	114.00	173.00	79.00
8/11/83	736	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	206.00	75.00
8/16/83	741	22.00	6.90	*****	184.00	*****	*****	247.00	*****	*****	*****	93.00	196.60	74.00
8/17/83	742	22.00	7.10	*****	174.00	55.00	56.00	243.00	*****	*****	*****	83.00	183.00	74.00
8/18/83	743	*****	7.90	44.00	97.00	25.00	19.00	232.00	*****	*****	*****	50.00	161.00	78.00
8/19/83	744	22.00	7.30	*****	192.00	65.00	73.00	236.00	*****	*****	*****	71.00	161.00	78.00
8/20/83	745	22.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	261.00	78.00
8/21/83	746	23.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	273.00	77.00
8/22/83	747	22.00	7.20	*****	693.00	139.00	178.00	229.00	*****	*****	*****	216.00	280.00	78.00
8/23/83	748	23.00	7.30	*****	403.00	153.00	191.00	266.00	*****	*****	*****	96.00	300.00	77.00
8/24/83	749	*****	7.20	*****	481.00	251.00	319.00	234.00	*****	*****	*****	111.00	428.00	78.00
8/25/83	750	*****	7.30	*****	721.00	369.00	480.00	243.00	*****	*****	*****	118.00	472.00	79.00
8/26/83	751	*****	*****	*****	259.00	35.00	35.00	*****	*****	*****	*****	110.00	619.00	76.00
8/27/83	752	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	37.70	*****
8/28/83	753	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.00	77.00
8/29/83	754	*****	*****	*****	*****	110.00	142.00	*****	*****	*****	*****	*****	74.00	75.00
8/30/83	755	*****	*****	*****	241.00	95.00	113.00	*****	*****	*****	*****	73.00	27.00	*****
8/31/83	756	*****	*****	*****	207.00	98.00	666.00	*****	*****	*****	*****	38.00	261.00	75.00

SUMMARY

HIGH	23.00	7.90	145.00	721.00	369.00	666.00	266.00	0.00	0.00	0.00	0.00	216.00	619.00	79.00
LOW	22.00	6.80	44.00	97.00	25.00	19.00	206.00	0.00	0.00	0.00	0.00	38.00	27.00	73.00
AVERAGE	22.15	7.18	67.40	287.88	109.21	168.94	234.15	0.00	0.00	0.00	0.00	89.47	224.32	75.84
STD. DEV.	0.38	0.27	43.52	188.36	91.97	179.89	15.30	0.00	0.00	0.00	0.00	41.40	126.69	1.97
NO. OF POINTS	13.00	14.00	5.00	17.00	16.00	16.00	13.00	0.00	0.00	0.00	0.00	17.00	26.00	25.00

DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	BOD5 (MG/L)	COD (MG/L)	VSS (MG/L)	ISS (MG/L)	ALK (MG/L)	NH4 (MG/L)	U.ALTDS (MG/L)	BOD5-S (MG/L)	COD-S (MG/L)	GAS (FT-3/D)	METHANE (% - U/V)
9/ 1/83	757	23.00	*****	*****	*****	98.00	666.00	*****	*****	*****	*****	*****	314.00	79.00
9/ 2/83	758	23.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	305.00	80.00
9/ 3/83	759	23.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	130.00	81.00
9/ 4/83	760	23.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	245.00	81.00
9/ 5/83	761	23.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	81.00
9/ 6/83	762	23.00	7.20	65.00	449.00	4.00	4.00	227.00	*****	*****	*****	49.00	359.00	74.70
9/ 7/83	763	23.00	7.10	67.00	156.00	34.00	44.00	*****	*****	*****	*****	74.00	213.00	81.00
9/ 8/83	764	23.00	7.30	*****	153.00	33.00	47.00	229.00	*****	*****	*****	79.00	207.00	81.00
9/ 9/83	765	23.00	6.90	*****	232.00	42.00	52.00	181.00	*****	*****	*****	162.00	303.00	78.00
9/10/83	766	23.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	197.00	80.00
9/11/83	767	23.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	74.00
9/12/83	768	23.00	7.40	*****	392.00	51.00	64.00	*****	*****	*****	*****	282.00	357.00	74.00
9/13/83	769	24.00	6.90	173.00	272.00	72.00	87.00	*****	*****	*****	*****	147.00	*****	*****
9/14/83	770	23.00	7.00	213.00	*****	30.00	30.00	*****	*****	*****	*****	140.00	69.00	1.00
9/15/83	771	23.00	6.80	*****	142.00	43.00	50.00	*****	*****	*****	*****	50.00	330.00	75.00
9/16/83	772	23.00	7.00	77.00	138.00	33.00	44.00	*****	*****	*****	*****	85.00	37.00	*****
9/17/83	773	23.00	7.00	*****	152.00	49.00	60.00	*****	*****	*****	*****	77.00	22.00	71.60
9/18/83	774	23.00	6.80	*****	180.00	55.00	66.00	*****	*****	*****	*****	117.00	*****	*****
9/19/83	775	23.00	7.00	125.00	130.00	46.00	59.00	*****	*****	*****	*****	59.00	*****	*****
9/20/83	776	23.00	7.00	87.00	124.00	49.00	57.00	*****	*****	*****	*****	55.00	*****	*****
9/21/83	777	23.00	6.70	108.00	87.00	22.00	24.00	184.00	*****	*****	*****	38.00	130.00	78.00
9/22/83	778	22.00	7.20	*****	147.00	24.00	31.00	*****	*****	*****	*****	62.00	129.00	73.00
9/27/83	783	22.00	7.10	*****	203.00	32.00	48.00	*****	*****	*****	*****	140.00	50.00	31.60
9/28/83	784	21.00	7.10	*****	79.30	30.00	43.00	*****	*****	*****	*****	42.30	91.00	43.00
9/29/83	785	22.00	*****	*****	87.00	38.00	52.00	*****	*****	*****	*****	38.00	101.00	54.70
9/30/83	786	21.00	*****	49.00	*****	46.00	660.00	*****	*****	*****	*****	*****	106.00	61.00

SUMMARY

HIGH	24.00	7.40	213.00	449.00	98.00	666.00	229.00	0.00	0.00	0.00	0.00	282.00	368.00	81.00
LOW	21.00	6.70	49.00	79.30	4.00	4.00	181.00	0.00	0.00	0.00	0.00	38.00	22.00	1.00
AVERAGE	22.77	7.03	116.40	183.72	41.55	109.40	205.25	0.00	0.00	0.00	0.00	94.24	193.48	48.36
STD. DEV.	0.65	0.18	59.36	102.54	19.48	190.12	26.31	0.00	0.00	0.00	0.00	61.93	117.11	20.43
NO. OF POINTS	26.00	17.00	10.00	17.00	20.00	20.00	4.00	0.00	0.00	0.00	0.00	18.00	21.00	21.00

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DATE	DAYS SINCE INOCULATION	TEMP (C)	PH	BOD5 (MG/L)	COD (MG/L)	VSS (MG/L)	TSS (MG/L)	ALK (MG/L)	NHA (MG/L)	U. ACIDS (MG/L)	BOD5-S (MG/L)	COD-S (MG/L)	GAS (FT-3/D)	METHANE (% - V/V)
10/ 1/83	787	21.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	80.00	66.30
10/ 2/83	788	21.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	40.00	69.00
10/ 3/83	789	21.00	7.40	*****	193.00	69.00	96.00	227.00	*****	*****	*****	69.00	59.00	62.00
10/ 4/83	790	21.00	7.20	*****	244.00	21.00	26.00	239.00	10.00	*****	*****	74.00	79.00	62.00
10/ 5/83	791	21.00	7.30	*****	339.00	45.00	56.00	201.00	*****	*****	*****	189.00	41.00	62.00
10/ 6/83	792	21.00	7.10	*****	320.00	40.00	52.00	191.00	*****	*****	*****	199.00	38.00	57.00
10/ 7/83	793	21.00	7.00	*****	327.00	44.00	53.00	208.00	*****	*****	*****	226.00	33.00	58.00
10/ 8/83	794	21.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	2.30	22.00
10/ 9/83	795	21.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	5.30	4.20
10/10/83	796	21.00	7.10	*****	187.00	25.00	27.00	227.00	*****	*****	*****	112.00	1.60	*****
10/11/83	797	20.00	7.20	*****	115.00	26.00	31.00	221.00	*****	*****	*****	71.00	2.00	4.20
10/12/83	798	21.00	7.10	*****	253.00	20.00	23.00	224.00	*****	*****	*****	168.00	3.40	6.30
10/13/83	799	20.00	*****	*****	126.00	26.00	28.00	*****	*****	*****	*****	223.00	3.30	*****
10/14/83	800	20.00	7.10	*****	135.00	18.00	25.00	191.00	*****	*****	*****	83.00	7.60	*****
10/15/83	801	20.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	7.30	*****
10/16/83	802	20.00	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0.50	5.30
10/17/83	803	20.00	6.90	*****	304.00	28.00	34.00	230.00	*****	*****	*****	197.00	*****	*****
10/18/83	804	20.00	7.20	*****	231.00	25.00	30.00	224.00	*****	*****	*****	97.00	*****	*****
10/19/83	805	20.00	7.20	*****	241.00	25.00	27.00	223.00	*****	*****	*****	140.00	*****	*****
10/20/83	806	20.00	7.10	*****	310.00	24.00	26.00	222.00	*****	*****	*****	185.00	4.40	*****

SUMMARY

HIGH	21.00	7.40	0.00	339.00	69.00	96.00	239.00	0.00	0.00	0.00	0.00	226.00	80.00	69.00
LOW	20.00	6.90	0.00	115.00	18.00	23.00	191.00	0.00	0.00	0.00	0.00	69.00	0.50	4.20
AVERAGE	20.55	7.15	0.00	237.50	31.14	38.14	217.54	0.00	0.00	0.00	0.00	145.21	23.98	39.86
STD. DEV.	0.51	0.13	0.00	77.27	13.86	20.12	15.04	0.00	0.00	0.00	0.00	59.41	27.78	28.32
NO. OF POINTS	20.00	13.00	0.00	14.00	14.00	14.00	13.00	1.00	1.00	0.00	0.00	14.00	17.00	12.00

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1. REPORT NO.		2.		3. RECIPIENT'S ACCESSION NO.	
4. TITLE AND SUBTITLE				5. REPORT DATE	
The Loves Creek Anaerobic, Upflow (ANFLOW) Pilot Plant: Performance Summary				March 1985 (Issuing Date)	
7. AUTHOR(S)				6. PERFORMING ORGANIZATION CODE	
M. T. Harris, T. L. Donaldson, R. K. Genung, A. L. Rivera, and C. W. Hancher				8. PERFORMING ORGANIZATION REPORT NO.	
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				14. SPONSORING AGENCY CODE	
				EPA/600/14	
15. SUPPLEMENTARY NOTES					
Project Officer: Ronald F. Lewis (513) 684-7644					
16. ABSTRACT					
Anaerobic filter technology for municipal wastewater treatment has been studied in Knoxville, Tennessee with a 190-m³/d facility from August 1981 to October 1983. The ORNL project (described by the acronym ANFLOW for the anaerobic, upflow characteristics of the technology) received funding from both DOE and EPA. During treatment of low-strength municipal wastewater before primary sedimentation, the effluent met the EPA secondary treatment discharge limits of 30 mg/L for TSS and BOD the vast majority of the time, with only an occasional increase to the 30 to 40 mg/L range for periods of 1 to 2 d. Loading rates used in this study were ~0.25 kg/m³·d for both TSS and MOD; the hydraulic retention time ranged from 9 to 10 h. TSS and BOD removal efficiencies were 80% and 70% respectively. This performance was maintained in ambient cold weather tests (~12°C water temperature). Approximately 20% of the influent carbon was converted to methane. Gas production increased at higher loading rates with higher strength wastewaters. The average rate of accumulation of dry solids in the bioreactor was ~150 kg/3800 m³ (3800 m³ = 1 million gal) of wastewater treated, which represents a 75 to 80% reduction in solids production compared to primary sedimentation and activated sludge or trickling filtration. The rate was slightly higher in cold weather and somewhat lower in warm weather. A simple material balance model was shown to predict the sludge accumulation using measurable influent and effluent parameters.					
17. KEY WORDS AND DOCUMENT ANALYSIS					
a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS		c. COSATI Field/Group	
Wastewater Anaerobic Filter		Municipal wastewater treatment			
18. DISTRIBUTION STATEMENT		19. SECURITY CLASS (This Report)		21. NO. OF PAGES	
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